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THEORY OF THE STRENGTH OF LONG COLUMNS.

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ALTHOUGH several new formulæ for determining the strength of columns have been recently proposed, and some comparison made between the numerical results obtained by experiment and from the different formulæ, there seems to have been no attempt to show that the formulæ now in general use are incorrect. The significance of the constants in Gordon's formulæ seems, indeed, to be not generally understood. It is the purpose of this paper to derive and discuss Gordon's and Hodgkinson's formulæ.

SHORT PRISMS.

As the resistance of materials to crushing has always been intimately associated with the theory of the strength of columns the method of obtaining the crushing strength will be briefly noticed. Malleable metals, such as wrought iron, when subjected to compression yield by buckling or by flowing laterally, and cannot strictly be said to have a crushing strength. However, the ultimate resistance of wrought iron to compression has been variously estimated at from 36000 to 90000 lbs. per square inch by different authors. This disagreement between the values assigned to the crushing strength must be attributed to the diversity of opinion as to what the crushing strength of such metals may be defined to be. When the material is of granular texture, prisms of not less than one and a half nor more than three diameters long, subjected to a compressive stress yield without flexure, fracture taking place along nearly plane surfaces. The values of the moduli of rupture thus obtained are evidently applicable to determine the strength of beams and columns made of granular materials, as these when fractured on the compressed side yield by a wedge being forced out at the point of rupture.

When a short prism is uniformly loaded the pressure is uniformly distributed over any ideal plane section. Therefore, if p represents the intensity of a uniform load applied to a prism bounded by horizontal and vertical faces, the intensity of vertical stress on any horizontal plane section is p; and on a section inclined at an angle ϑ to the horizon is $p.\cos\vartheta$. The intensities of the tangential and normal components of stress on this plane are respectively

$$p.\cos\vartheta.\sin\vartheta = p_t, \text{ and } p.\cos^2\vartheta = p_n.$$

Let f represent the coefficient of friction —assumed to be constant—of the material at the point of abrasion; then the intensity of frictional resistance to the separation of the prism at any plane section is $f.p_n = f.p.\cos^2\vartheta$. The intensity of stress tending to produce fracture along any plane is therefore

$$p_\vartheta = p(\cos\vartheta.\sin\vartheta - f.\cos^2\vartheta) \quad . \quad . \quad . \quad (1)$$

Fracture will evidently take place along the plane which has such an inclination that p_ϑ has its maximum value on that plane. To find the inclination of the plane for which p_ϑ is a maximum equate

$\frac{dp_\vartheta}{d\vartheta}$ to zero, and then solve for ϑ.

$$\frac{dp_\vartheta}{d\vartheta}=p[\cos^2\vartheta-\sin^2\vartheta+2f.\sin\vartheta.\cos\vartheta]=0$$

$$\therefore\ \cos^2\vartheta-\sin^2\vartheta+2f.\sin\vartheta.\cos\vartheta=0$$

and $$\vartheta_m=\tan^{-1}(f+\sqrt{1+f^2}) \quad . \ . \ . \quad (2)$$

The positive sign is given to the radical in (2) because ϑ_m must be greater than 45°. For when 0 is substituted for f in (2) the value of ϑ_m is 45°; and since f is always greater than zero, ϑ_m must be greater than 45°, for p_n will then be less than p_t as it evidently must be when p_ϑ has its maximum value. As there are an infinite number of plane sections of equal areas inclined at the angle ϑ_m, it is obvious that when a prism of homogeneous material yields to compression two cones, whose vertices lie at the same point in the axis of the prism, will be formed. If the material is not homogeneous the prism will be fractured along the plane where the resistance is least. It is evident, therefore, that the resistance of prisms of the same material to compression is proportional to the area of the cross-section. If 0.4, which is the value of the coefficient of friction for cast iron at the point of abrasion determined by Rennie, be substituted in eq. (2) for f, then $\vartheta_m=\tan^{-1}1.477=55°54'$. This value corresponds with the empirical value of ϑ_m found by Hodgkinson, who states in his work on cast iron that ϑ_m is somewhat less than 56°.

If the deviation of the plane of fracture from the inclination of 45° for which p_t is a maximum is wholly due to the action of a force analagous to friction, as has been assumed above, it follows that p_ϑ is of such magnitude that the frictional resistance and the resistance to shearing along the surface of fracture are together equal to p_ϑ. If, then, $f.p.\cos^2\vartheta$, which is the intensity of frictional resistance, be subtracted from p_ϑ, the modulus of shearing will be obtained. Let S denote the modulus of shearing, then

$$S=p[\cos\vartheta.\sin\vartheta-2f.\cos^2\vartheta].$$

Substitute for p the value of the modulus of rupture for cast iron of the brand "Low Moor No. 3," which is 109801 lbs., and make $f=0.4$ and $\vartheta=55°54'$; then $S=.213\times109801=23387$ lbs. Rankine gives 27000 lbs. as the average value of S for cast iron. This relation between the crushing and shearing strengths of materials can be verified by experiment alone.

When prisms too short to be fractured by shearing are compressed the length of the prism is decreased, the right section is augmented, and the prism is fractured when the strain produced by lateral enlargement overcomes the cohesion of the particles of the material. In this change of form the friction between the ends of the prism and the surfaces, between which the prism is crushed prevents, to some extent, lateral spreading of the material there, and thus adds an important element of strength to the prism. Although the friction increases with increase of intensity of pressure, and is therefore greater the stronger the material, yet it is not known that the influence of the friction on the apparent strength of such prisms is proportional to the strength of the material. So that moduli of resistance obtained from experiments on such prisms are greater than the intrinsic strength, and are not known to represent the relative strength to resist crushing except under the peculiar conditions of the experiments.

LONG COLUMNS.

The strength of prisms of such length that when subjected to compression they deflect appreciably from a straight line is determined by the formulæ for the strength of long columns. The power of long columns to resist fracture, other things being equal, depends on the method of supporting the ends; and it is usual on this basis to classify long columns under three general heads, according as they are free to turn about both ends; are fixed at both ends; or are fixed at one end and free to turn about the other end.

COLUMNS FREE TO TURN ABOUT BOTH ENDS.

Let the neutral axis of a column free to turn about both ends be referred to rectangular co-ordinates, the origen being at one end, and the axes of X and Y vertical and horizontal respectively. Let the load supported by the column be denoted by P. Then, since the moment of internal resistance at any section must be equal to the moment of the external forces,

$$\mathrm{P}.y=\frac{\mathrm{EI}}{\mathrm{R}}=\mathrm{EI}\,\frac{-\dfrac{d^2y}{dx^2}}{\left\{1+\left(\dfrac{dy}{dx}\right)^2\right\}^{\frac{3}{2}}}$$

the negative sign being used because the curve is concave to the axis of X. As the curvature of the column is practically very slight, the inclination of the column to X and therefore $\frac{dy}{dx}$ also will be very small at any point; so that $\left(\frac{dy}{dx}\right)^2$ may without material error be neglected in the expression for $\mathrm{P}.y$. The equation of moments may then be written

$$\frac{d^2y}{dx^2}+\mathrm{P}.y.\frac{1}{\mathrm{EI}}=0.$$

This is a "linear" equation the complete integral of which is

$$y=(c_1+c_2)\cos\left\{x\sqrt{\frac{\mathrm{P}}{\mathrm{EI}}}\right\}+\sqrt{-1}\,(c_1-c_2)\sin\left\{x\sqrt{\frac{\mathrm{P}}{\mathrm{EI}}}\right\},$$

c_1 and c_2 being constants of integration. Since $y=0$ when $x=0$, therefore $c_1=-c_2$ and

$$y=2c_1\sqrt{-1}\sin\left\{x\sqrt{\frac{\mathrm{P}}{\mathrm{EI}}}\right\}=h\sin\left\{x\sqrt{\frac{\mathrm{P}}{\mathrm{EI}}}\right\}\quad .\quad .\quad .\quad (3)$$

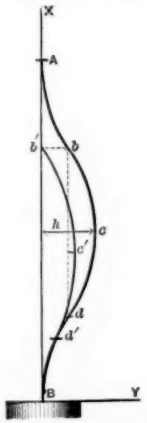
where $2c_1\sqrt{-1}=h$ for convenience. If the curvature of the column be so slight that the abscissa of the end of the column differs inappreciably from the length of the column, equation (3) gives for this point

$$0=h\sin\left\{l\sqrt{\frac{\mathrm{P}}{\mathrm{EI}}}\right\}$$

where l is the length of the column. Since $\sqrt{\frac{\mathrm{P}}{\mathrm{EI}}}$ cannot be zero it follows that $l.\left\{\sqrt{\frac{\mathrm{P}}{\mathrm{EI}}}\right\}=n.\pi$; n being some whole number. Now $\left\{x.\sqrt{\frac{\mathrm{P}}{\mathrm{EI}}}\right\}=0$ when $x=0$; so that as x changes from 0 to l, $x.\sqrt{\frac{\mathrm{P}}{\mathrm{EI}}}$ changes from 0 to $n.\pi$, and must therefore pass through the value $\frac{\pi}{2}$. When $x.\sqrt{\frac{\mathrm{P}}{\mathrm{EI}}}=\frac{\pi}{2}$, y has its maximum value h, which corresponds to the abscissa $x=\frac{l}{2}$. If n be greater than unity there will evidently be n values of x that make $\sin\left\{x\sqrt{\frac{\mathrm{P}}{\mathrm{EI}}}\right\}=1$, and there will therefore be n points at which $y=h$; but as there can be only one such point n must be unity. The value of P found from equation (3) when n is unity is

$$\mathrm{P}=\frac{\pi^2\mathrm{EI}}{l^2}\quad .\quad .\quad .\quad (4)$$

This is the equation proposed by Euler for determining the strength of uniform



elastic columns which are free to turn about the ends, and erroneously supposed to express the resistance to "incipient flexure."

COLUMNS FIXED AT BOTH ENDS.

If the column is not free to turn about the ends but is fixed vertically there, the

line AcB in the figure represents on an exaggerated scale the curvature of the neutral axis of such a column. Fixing a column at the ends is equivalent to introducing a couple at each end of such magnitude as to keep the tangents there always vertical. Let M represent the moment of the end couple. The equation of moments for any section is then

$$P.y - M = \frac{EI}{R} = -EI.\frac{d^2y}{dx^2},$$

if the flexure is so small that $\left(\frac{dy}{dx}\right)^2$ may be neglected in the value of R. The value of y found by equating $\frac{d^2y}{dx^2}$ to zero is $y=\frac{M}{P}$, which is the value of y at the points of inflexion b and d. Substitute z for $\frac{dy}{dx}$ in the equation of moments, multiply by $z.dx = dy$, and integrate; then

$$\tfrac{1}{2}z^2 = \frac{M}{EI}.y - \tfrac{1}{2}\frac{P}{EI}.y^2 + c,$$

or, replacing z by $\frac{dy}{dx}$,

$$\left(\frac{dy}{dx}\right)^2 = \frac{2M}{EI}.y - \frac{P}{EI}.y^2 + c.$$

Since $\frac{dy}{dx}=0$ when $y=0$, the constant of integration c is zero

$$\therefore \left(\frac{dy}{dx}\right)^2 = \frac{-P}{EI}.y^2 + \frac{2M}{EI}.y \quad . \quad . \quad . \quad (5)$$

The maximum value of y, found by equating $\frac{dy}{dx}$ to zero, is $y=\frac{2M}{P}$. Equation (5) solved for dx and then integrated gives

$$x = \sqrt{\frac{EI}{P}}\left\{\cos^{-1}\left(\frac{P.y}{M} - 1\right)\right\} + c.$$

The value of c, found by making x and y zero, is

$$c = -\sqrt{\frac{EI}{P}}(2n-1)\pi.$$

$$\therefore x = \sqrt{\frac{EI}{P}}\left\{\cos^{-1}\left(\frac{P.y}{M} - 1\right) - (2n-1)\pi\right\}.$$

This equation solved for y gives

$$y = \frac{M}{P}\left\{1 + \cos\left(x\sqrt{\frac{P}{EI}} + (2n-1)\pi\right)\right\}$$

$$= 2\,\frac{M}{P}.\sin^2\left\{\frac{x}{2}\sqrt{\frac{P}{EI}}\right\} \quad . \quad . \quad . \quad (6)$$

In this equation substitute for y its maximum value $\frac{2M}{P}$, and for x substitute $\frac{l}{2}$, which is the abscissa of the middle point c when l differs inappreciably from the abscissa of the end of the column; then

$$\frac{2M}{P} = \frac{2M}{P}\sin^2\left\{\frac{l}{4}\sqrt{\frac{P}{EI}}\right\} \quad \therefore \frac{l}{4} = \frac{\pi}{2}\sqrt{\frac{EI}{P}}.$$

Now in equation (6) substitute $\frac{M}{P}$, the value of y at the points of inflexion, for y; then

$$\sin\left\{\frac{x}{2}\sqrt{\frac{P}{EI}}\right\} = \frac{1}{\sqrt{2}} \text{ and } x = \frac{\pi}{2}\sqrt{\frac{EI}{P}}$$

$$\text{or } \frac{3\pi}{2}\sqrt{\frac{EI}{P}} = \frac{l}{4} \text{ or } \frac{3l}{4}.$$

Thus the points of inflexion divide the column into segments such that $Ab = bc = cd = dB$ in the figure. Since $y=0$ when $x=l$, equation (6) becomes, when l is substituted for x,

$$\sin\left\{\frac{l}{2}\sqrt{\frac{P}{EI}}\right\} = 0. \quad \therefore \frac{l}{2}\sqrt{\frac{P}{EI}} = n\pi$$

where n must be unity for the same reasons as in the case of columns free to turn about the ends. The value of P found from this equation is

$$P = \frac{\pi^2 EI}{\left(\frac{l}{2}\right)^2} = \frac{4\pi^2 EI}{l^2} \quad . \quad . \quad . \quad (7)$$

From this equation it appears that as regards resistance to flexure a column fixed at the ends has the same strength as one half as long and free to turn about the ends.

COLUMNS FIXED AT ONE END.

It is evident from the figure that the stress in each of the segments Ab, bc, cd, dB of a column fixed at both ends is the same as the stress in either half of a column free to turn about both ends, and twice as long as one of the segments. The portion bcd of the column

will therefore represent a column of the same strength which is free to turn about the ends b and d. The value of P for a column free to turn about the ends given in eq. (4) is expressed in terms of l, the length of the column; so that if l_1 denote half the length of the column, $P=\frac{\pi^2EI}{(2l_1)^2}$. This equation is true then for each of the four equal segments of a column fixed at the ends, when l_1 is the length of each segment. Since at the point of inflexion b there is no flexure, the stress in the rest of the column will not be altered if the part above b is removed and the load is applied directly at b. The value of P for each of the segments bc, cd, dB of length l_1, and, therefore, for the whole columns is

$$P=\frac{\pi^2EI}{(2l_1)^2}=\frac{\pi^2EI}{\left(\frac{2l}{3}\right)^2}=\frac{9\pi^2EI}{4l^2} \quad \ldots \quad (8)$$

where l is the length of the column bB. Suppose the end b to be now moved to the point b' on the vertical tangent to the neutral axis at B. The flexure in the segment bcd will thereby be increased, while the flexure in the segment db will be diminished; and the neutral axis will assume the position $b'c'd'$B, and will then represent the curvature of the neutral axis of a column fixed at one end and free to turn about the other end. Although equation (8) is thus seen to be not strictly true for such a column, yet as bb' is very small this equation is considered to be sufficiently near the truth for practical purposes.

The expressions for P deduced by considering the stress induced by flexure alone are constant for a given column, provided the deflection is small, and hence follows the conclusion of Euler that P is the power of columns to resist "incipient flexure." But the strength of the material is reduced by an amount equal to the compressive stress produced by the direct action of P, so that, if P is to express the ultimate strength of the column, the values of P found above must be reduced by this amount. Let c denote the modulus of rupture for compression of the material, and let $\frac{P}{S}=Q$ be the intensity of compressive stress due to the direct action of P, where S=area of cross-section. Then $\frac{Q}{c}$ is the part of c that is overcome by the direct action of P, and therefore $\left(1-\frac{Q}{c}\right)$ is the part of c that is free to resist stress induced by flexure. So that, since the transverse strength is proportional to the modulus of rupture, the true value of the ultimate strength of columns is found by multiplying the values of P in equations (5),(7) and (8) by $\left(1-\frac{Q}{c}\right)$. Substitute Q.S for P in these equations so altered, and solve for Q; then for columns

Free to turn about both ends

$$Q=\frac{c}{1+\frac{c}{\pi^2E}\cdot\frac{Sl^2}{I}}=\frac{c}{1+\frac{c}{\pi^2E}\left(\frac{l}{\rho}\right)^2} \quad \ldots (9)$$

Fixed at both ends

$$Q=\frac{c}{1+\frac{c}{4\pi^2E}\cdot\frac{Sl^2}{I}}=\frac{c}{1+\frac{c}{4\pi^2E}\left(\frac{l}{\rho}\right)^2} \quad \ldots (10)$$

Fixed at one end

$$Q=\frac{c}{1+\frac{4c}{9\pi^2E}\cdot\frac{Sl^2}{I}}=\frac{c}{1+\frac{4c}{9\pi^2E}\left(\frac{l}{\rho}\right)^2} \quad \ldots (11)$$

(A)

In these equations I is the least moment of inertia, and ρ is the least radius of gyration of the transverse section of the column. These formulæ which are seen to have the same general form as Rankine's formulæ were proposed by John D. Crehore in the December number of this Magazine for 1879; and differ from Rankine's formulæ in the more definite form of the second term of the denominator.

Equation (9), (10) and (11) are founded on the hypothesis that the material is fractured by a compressive stress. Since the compression due to flexure acts with and augments the stress due to the direct action of the load, it follows that the material on the concave side of the curve assumed by a loaded column is more severely strained than on the convex side, where the tension produced by flexure is wholly or partly neutralized by the compression due to the load. But when the tensile strength of a material is much

less than the compressive strength, a column made of such material may yield on the convex side to the tensile stress induced by flexure. When such is the case, if t denote the modulus of rupture for tension and Q as before the unit stress due to the direct action of the load, then $\frac{Q}{t}$ is the part of t by which the strength of the column to resist tension is increased. So that the true value of the ultimate strength of columns is found by multiplying the values of P in equations (5), (7) and (8) by $\left(1+\frac{Q}{t}\right)$. Substitute Q.$s$ for P in the equations so altered, and solve for Q; then for columns

Free to turn about both ends

$$Q=\frac{t}{\frac{t}{\pi^2 E}\left(\frac{l}{\rho}\right)^2-1} \quad . \quad . \quad . \quad (12)$$

Fixed at both ends

$$Q=\frac{t}{\frac{t}{4\pi^2 E}\left(\frac{l}{\rho}\right)^2-1} \quad . \quad . \quad . \quad (13) \quad \} \text{(B)}$$

Fixed at one end

$$Q=\frac{t}{\frac{4t}{9\pi^2 E}\left(\frac{l}{\rho}\right)^2-1} \quad . \quad . \quad . \quad (14)$$

Where ρ as before denotes the least radius of gyration of the transverse section of the column. It is thus seen that it is possible to have two formulæ for determining the value of Q for any particular column. The correct value of Q is evidently determined by the formulæ that gives the less result, and according as this formula is one of set (A) or of set (B) the column yields to compression or tension.

Cast iron, if we except stone, is the only material ordinarily used for columns that fulfills this condition; the average ratio of the crushing strength of cast iron to the tensile strength being about six. The moduli of rupture of cast iron of the brand "Low Moor No. 3" for compression and tension are 109,801 lbs. and 14,535 lbs. respectively. And in the experiments of Hodgkinson on solid cylindrical columns of this brand of cast iron, all columns with rounded ends when more than ten diameters long, and all with flat ends when more than about eighteen diameters long, were torn asunder on the convex side by the tensile strain due to flexure. This may be easily verified from Hodgkinson's experiments by dividing the breaking weights by the area of cross section of the columns to find Q, and then adding this value of Q to the modulus of rupture for tension and substracting it from the modulus of rupture for compression to get the unit stress due to flexure necessary to break the column. The process that gives the less result evidently determines whether the column yields to tension or compression. So that if t and c denote the moduli of rupture for tension and compression, then if $(t+Q)<(c-Q)$, the column yields to tension; and if $(t+Q)>(c-Q)$ the column yields to compression. When $(t+Q)=(c-Q)$ the column will yield equally to tension and compression.

TABLE I.

Columns with Flat Ends.			Columns with Round Ends.		
$\frac{l}{d}$	$(t+Q)$	$(C-Q)$	$\frac{l}{d}$	$(t+Q)$	$(C-Q)$
9.7	82045	42291	9.8	63815	60521
13.1	70495	53841	13.2	53135	71201
15.1	65785	56551	15.2	40195	84141
19.5	60135	64201	19.9	32625	91711
19.7	53305	71031	23.4	27725	96611
24	51178	73158			

If the moduli of rupture of the cast iron used by Hodgkinson in his experiments be substituted for t and c in the above equation, then $[14535+Q]=[109801-Q]$, and this gives Q=47633 lbs.; so that $[t+Q]=[C-Q]=62168$. In the accompanying table the values of $[t+Q]$ and $[C-Q]$ calculated from Hodgkinson's experiments, are seen to approach the value 62168 as $\frac{l}{d}$ approaches 18 when the ends are flat, and 10 when the ends are round. The yielding of long cast iron columns to tension accounts for the greater strength of long wrought iron columns.

GORDON'S FORMULAE.

For Cast Iron. — The fundamental hypothesis on which the above discussion depends is, that E, the modulus of elasticity, is constant. As is well known,

however, this is not the case when the material is strained to near the ultimate strength, and hence it might be inferred that the general formulæ deduced on this hypothesis cannot be used to determine the ultimate strength of columns. The coefficient of $\left(\frac{l}{\rho}\right)^2$ in formulæ (A) and (B) is the product of some constant into $\frac{C}{\pi^2 E}$ or $\frac{t}{\pi^2 E}$; so that if E is constant the whole coefficent of $\left(\frac{l}{\rho}\right)^2$ is constant, and (A) and (B) may be replaced by the general formulæ

$$Q=\frac{c}{1+a\left(\frac{l}{\rho}\right)^2} \quad . \quad . \quad . \quad (15)$$

and

$$Q=\frac{t}{a\left(\frac{l}{\rho}\right)^2-1} \quad . \quad . \quad . \quad (16)$$

where to a must be assigned the values of the coefficients of $\left(\frac{l}{\rho}\right)^2$ in (A) and (B). When the column is a solid cylinder the value of ρ in terms of the diameter d of the transverse section is $\rho^2=\frac{d^2}{16}$; and when this value is substituted for ρ^2 in equations (15) and (16) the general equations for solid cylindrical columns are

$$Q=\frac{c}{1+16a\left(\frac{l}{d}\right)^2} \text{ and } Q=\frac{t}{16a\left(\frac{l}{d}\right)^2-1}.$$

Let a_r denote the value of $16a$ for columns free to turn about the ends, and a_f for columns fixed at both ends. The values of a_r and a_f computed from the experiments of Hodgkinson on solid cylindrical cast iron columns are given in table II. Equations (15) or (16) was used in these computations according as the columns yielded to compression or tension, and to c and t were given the values $c=109801$ lbs., and $t=14535$ lbs. The device adopted by Hodgkinson to allow the columns free motion about the ends was to make the ends rounded; and to fix the ends he made them flat. It appears from equations (A) and (B) that the coefficient of $\left(\frac{l}{d}\right)^2$ should have the same value for columns fixed at both ends that it has for a column half as long and free to turn about both ends; and in order that the comparative values of a_r and a_f may be more readily apparent $2l$ is substituted for l for columns fixed at both ends. So that instead of the values of a_f corresponding to different values of $\frac{l}{d}$, we have the values of $4a_f$ which correspond to different values of $\frac{l}{2d}$. The lengths of the columns are given in inches. The value of a instead of being constant is seen to increase quite uniformly as $\frac{l}{d}$ decreases, the greatest value of a_r when $\frac{l}{d}=9.8$ being nearly ten times the value for $\frac{l}{d}=121$; and the value of $4a_f$ for $\frac{l}{2d}=6.6$, being more than ten times the value for $\frac{l}{2d}=60.5$.

Since when c and t are made equal to the moduli of rupture the coefficient of $\left(\frac{l}{\rho}\right)^2$ is not constant, if it is possible for this coefficient to be constant when to c in equation (15) is assigned some value other than the modulus of rupture, let f denote this value of c. The general equation then is

$$Q=\frac{f}{1+a\left(\frac{l}{\rho}\right)^2} \quad . \quad . \quad . \quad (17)$$

which for solid cylindrical columns, when ρ is expressed in terms of the diameter d, becomes

$$Q=\frac{f}{1+16a\left(\frac{l}{d}\right)^2}.$$

If different values be assigned to a, and the corresponding values of f be computed from the values of Q found by experiment, it is found that when a_f is less than about $\frac{1}{100}$, f increases as $\frac{l}{d}$ decreases, and when a_f is greater than

TABLE II.—CAST IRON.

Round Ends.					Flat Ends.				Discs on Ends.	
l	$\frac{l}{d}$	a_r	f when $a_r=\frac{1}{1000}$	f when $a_r=\frac{1}{2000}$	$\frac{l}{2d}$	$4a_f$	f when $a_f=\frac{1}{4000}$	f when $a_f=\frac{1}{2000}$	$\frac{l}{d}$	f when $16a=\frac{1}{8000}$
	121	.001432	104900	54020	60.5	.001939	89630	176900	121	46010
	78.6	.001567	105100	53410	39.2	.002438	86530	167800	78	49600
	61.1	.001844	94710	48580	30.6	.002953	85530	162800	60.5	48610
60.5	46.9	.001968	100400	52400	23.5	.003970	72840	147400	47.2	48380
	39.8	.002164	100800	53380	19.4	.005204	72170	129200	39.5	49400
	34.2	.002808	80740	43560						
	31.2	.002965	84410	46240						
	60.5	.001720	103120	52960	30.2	.002969	85910	163350	30.2	61350
	39.2	.002266	95823	50840	19.6	.004600	91630	164300		
30.25	30.5	.003148	81690	43790	15.0	.006992	82390	139400		
	23.4	.003839	85430	49340					Mean, 50560	
	19.9	.004556	89720	53900						
20.1	19.9	.004851	77402	46500	20.2	.004364	94920	171100		
	26.2	.002517	112300		12.9	.008564	88180	143200		
					9.8	.014172	76370	114000		
	30.2	.002731	98110	53910	15.1	.006288				
15.1	19.9	.004331	100800	60580	9.8	.013948	88920	132200		
	15.2	.006780	84920	55290	7.6	.019968	80460	109600		
12.1					12.1	.009540	90330	144000		
					7.7	.020020	79920	109600		
10.0	13.2	.007847			10.1	.012928	91880	138250		
					6.6	.022424	80030	104100		
7.56	15.2	.006649	89780	58180	7.6	.016012	90000	122700		
	9.8	.012790	96590		4.8	.016820	83370	99240		
Mean values.....			94039	51617			84790	138902		

about $\frac{1}{4000}$, f decreases as $\frac{l}{d}$ decreases. It follows, therefore, that f must be constant for some value of a_f a little greater or less than $\frac{1}{4000}$. The mean value of f when $a_f=\frac{1}{4000}$ is 84790, and none of the values of f differ from the mean value more than 15 per cent. The variations in the values of f seem due to empirical anomalies, and are independent of change in the value of $\frac{l}{d}$. If 80000 be taken as the value of f, the value of Q for solid cylindrical columns with flat ends is,

$$Q=\frac{80000}{1+\frac{1}{400}\left(\frac{l}{d}\right)^2};$$

and the general equation for columns with flat ends, found by substituting for d its value in terms of ρ, is

$$Q=\frac{80000}{1+\frac{1}{6400}\left(\frac{l}{\rho}\right)^2} \quad . \quad . \quad . \quad (18)$$

In "Trautwine's Engineer's Pocket Book" the coefficient of $\left(\frac{l}{\rho}\right)^2$ is given as $\frac{1}{32000}$ instead of $\frac{1}{64000}$. This value makes $a_f=\frac{1}{20000}$, and it is seen from the table that the corresponding value of f decreases as $\frac{l}{d}$ decreases, so that a_f must be less than $\frac{1}{20000}$. Also the mean value of f is nearly 139000 instead of 80000.

If simply making the ends of a column flat were sufficient to keep the column fixed in direction at the ends, then it follows from equations (9) and (10) that equation (18) will determine Q correctly for a column free to turn about the ends when $2l$ is substituted for l. When this substitution is made, $a_r=4a_f=\frac{1}{1000}$; and the corresponding values of f in the table are seen to decrease as $\frac{l}{d}$ decreases, the mean value of f being 94000. Since f decreases as $\frac{l}{d}$ decreases a_r must be less than $\frac{1}{1000}$. When $a_r=\frac{1}{2000}$ the

mean value of f is 51617, and the variations in the value of f seem to be independent of changes in the value of $\frac{l}{d}$. If 50000 be taken as the value of f the value of Q for solid cylindrical columns with round ends is

$$Q=\frac{50000}{1+\frac{1}{200}\left(\frac{l}{d}\right)^2};$$

and the general equation for columns with round ends, found by substituting for d its value in terms of ρ, is

$$Q=\frac{50000}{1+\frac{1}{3200}\left(\frac{l}{\rho}\right)^2}. \quad . \quad . \quad (19)$$

Hodgkinson found by experiment that cylindrical columns with flat discs on the ends are stronger than columns that have simply flat ends. As this additional strength can only be due to the fact that the discs hold the ends more firmly fixed than the flat ends of the column itself, it follows that a column with flat ends is not rigidly fixed in position there, but holds some place intermediate between a column free to turn about the ends and one fixed at the ends; so that the formula for columns free to turn about the ends cannot be derived directly from the formula for columns with flat ends, as has been found above. When, however, $\frac{l}{2}$ is substituted for l in eq. (19) the resulting equation should give the values of Q for columns with discs on the ends, provided the discs are sufficiently large to hold the ends rigidly in position. The general equation for columns fixed at the ends is then

$$Q=\frac{50000}{1+\frac{1}{12800}\left(\frac{l}{\rho}\right)^2} \quad . \quad . \quad (20)$$

which gives for cylindrical columns, when $\frac{d}{16}$ is substituted for ρ^2,

$$Q=\frac{50000}{1+\frac{1}{800}\left(\frac{l}{d}\right)^2}.$$

The values of f, computed from Hodgkinson's experiments, on solid cylindrical columns with discs on the ends, given in the table, are somewhat less than the values of f for columns free to turn about the ends; the mean value, omitting the last, being 48600. This discrepancy can only be accounted for by supposing the discs not large enough to secure the ends rigidly. If in equation (19) $\frac{2l}{3}$ be substituted for l the resulting equation will, according to eq. (11), be the formula for determining the strength of columns fixed at one end and free to turn about the other end; so that

$$Q=\frac{50000}{1+\frac{1}{7200}\left(\frac{l}{\rho}\right)^2} \quad . \quad . \quad . \quad (21)$$

is the general equation for columns fixed at one end. For solid cylindrical columns this becomes, on substituting for ρ^2 its value in terms of the diameter,

$$Q=\frac{50000}{1+\frac{1}{450}\left(\frac{l}{d}\right)^2}.$$

In the only experiment on a cylindrical column with a disc on one end, recorded by Hodgkinson, the length of the column was 30.25 inches, the diameter was one inch, and the empirical value of Q was 17272 lbs.; while equation (21) gives Q=16815 lbs. Hodgkinson gives three experiments on columns flat at one end and free to turn about the other end; but in the absence of more data equation (21), which gives results somewhat less than these experiments, seems the best that can be derived for columns flat at one end. The general formulæ for cast iron collected together for convenient reference are then, for columns—

Free to turn about both ends

$$Q=\frac{50000}{1+\frac{1}{3200}\left(\frac{l}{\rho}\right)^2}$$

Fixed at both ends

$$Q=\frac{50000}{1+\frac{1}{12800}\left(\frac{l}{\rho}\right)^2}$$

Fixed at one end

$$Q=\frac{50000}{1+\frac{1}{7200}\left(\frac{l}{\rho}\right)^2}$$

Flat at both ends

$$Q=\frac{80000}{1+\frac{1}{6400}\left(\frac{l}{\rho}\right)^2}$$

WROUGHT IRON.

Since the tensile strength of wrought iron is fully as great as its compressive strength, wrought iron columns always yield to a compressive strain, so that the general formula for wrought iron is

$$Q=\frac{c}{1+a\left(\frac{l}{\rho}\right)^2}$$

where to a must be assigned the values of the coefficient of $\left(\frac{l}{\rho}\right)^2$ in equations (A). But since the value of c has never been accurately determined, and as the same objection to the use of formulæ in which E is considered to be constant holds as well for wrought iron as for cast iron, the general formula may be written

$$Q=\frac{f}{1+a\left(\frac{l}{\rho}\right)^2}$$

where a and f are to be found empirically. The values of f in table III are computed from the experiments of Hodgkinson on solid rectangular and cylindrical columns. When the column is rectangular, if h denote the less side of the rectangle, $\rho^2=\frac{h^2}{12}$; and when the column is cylindrical, if d denote the diameter of the cylinder, $\rho^2=\frac{d^2}{16}$. So that the general formula for rectangular columns is

$$Q=\frac{f}{1+12a\left(\frac{l}{h}\right)^2}$$

and for cylindrical,

$$Q=\frac{f}{1+16a\left(\frac{l}{d}\right)^2}.$$

From the values of f in the table for columns with flat ends it is seen that f increases as $\frac{l}{h}$ increases, when $12a=\frac{1}{1000}$, and therefore $12a$ must be less than $\frac{1}{1000}$. When $12a=\frac{1}{3000}$ the mean value of f, omitting the first, is 36699 for rectangular columns, and the mean value for cylindrical columns is 36985. The value assigned to f for $12a=\frac{1}{3000}$, by Gordon, is 36000; and if this value is retained the formula for rectangular columns is

$$Q=\frac{36000}{1+\frac{1}{3000}\left(\frac{l}{h}\right)^2}$$

and for cylindrical columns

$$Q=\frac{36000}{1+\frac{1}{2250}\left(\frac{l}{d}\right)^2}$$

The general formula for wrought iron columns with flat ends, derived from the preceding formulæ by substituting for d and h their values in terms of ρ, is

$$Q=\frac{36000}{1+\frac{1}{36000}\left(\frac{l}{\rho}\right)^2} \quad \ldots \quad (22)$$

The values of f when $12a=\frac{1}{2500}$ and $16a=\frac{1}{1875}$ seem to be more uniform than when $12a=\frac{1}{3000}$ and $16a=\frac{1}{2250}$, but the difference is not great except for the first column where the value of $\frac{l}{h}$ is 7.3.

It has been shown that a cast iron column is not rigidly fixed in direction at the ends when the ends are flat, and the few experiments made by Hodgkinson on wrought iron columns with rounded ends indicate that this is also true for wrought iron columns. If a column with flat ends were rigidly fixed, then according to eq. (9) the value of Q for columns with rounded ends would be given by eq. (22) when $2l$ is substituted for l; so that

$$Q=\frac{36000}{1+\frac{1}{9000}\left(\frac{l}{\rho}\right)^2}$$

would be the formula for columns with rounded ends. This gives for solid cylindrical columns of diameter d

$$Q=\frac{36000}{1+\frac{1}{562}\left(\frac{l}{d}\right)^2}$$

The values of f in the table corresponding to $16a=\frac{1}{562}$ increase as $\frac{l}{d}$ decreases, and therefore $16a$ must be greater than $\frac{1}{562}$. When $16a=\frac{1}{400}$ the variations in

TABLE III. WROUGHT IRON.

Rectangular Columns. Flat Ends.

$\frac{l}{h}$	f when $12a=\frac{1}{1000}$	f when $13a=\frac{1}{2500}$	f when $12a=\frac{1}{3000}$
7.3	53650	45350	49550
14.6	43860	37500	37010
29.3	49290	34050	32600
30	56340	40330	38550
39	70010	44660	41860
58.6	80300	40980	37020
59	89570	47820	43190
60	77480	41100	37060
60	83110	44080	39740
60	81370	43160	38920
78	91910	44550	39290
80	75220	36190	31850
88	85280	39950	34930
90	90090	41970	36630
90	84440	39350	34340
118	83630	36810	31620
119	86380	37955	32570
	Mean	40936	36699

Cylindrical Columns. Flat Ends.

$\frac{l}{d}$	f when $16a=\frac{1}{1575}$	f when $16a=\frac{1}{2250}$
15.4	38480	37760
29.8	42560	40280
59.3	45710	40740
88.9	38610	29160
	41340	36985

Round Ends.

$\frac{l}{d}$	f when $16a=\frac{1}{562}$	f when $16a=\frac{1}{1000}$
15.4	42480	47250
19.8	43710	50980
58.1	41780	55850
59.6	28300	48080
89.2	33740	46500
	Mean	49732

the value of f are independent of the values of $\frac{l}{d}$, so that, if 49000 be taken as the value of f, the formula for solid cylindrical columns with rounded ends is

$$Q=\frac{49000}{1+\frac{1}{400}\left(\frac{l}{d}\right)^2}$$

The general formula for columns free to turn about the ends, found by substituting $16\rho^2$ for d^2, is

$$Q=\frac{49000}{1+\frac{1}{6400}\left(\frac{l}{\rho}\right)^2} \quad . \quad . \quad . \quad (23)$$

The formula for columns fixed at the ends is derived from eq. (23) by substituting $\frac{l}{2}$ for l in that equation; so that for columns fixed at the ends

$$Q=\frac{49000}{1+\frac{1}{25600}\left(\frac{l}{\rho}\right)^2} \quad . \quad . \quad . \quad (24)$$

The only experiment on a column with discs on the ends recorded by Hodgkinson was made on a solid cylindrical column 30.25 inches long and 1.015 inches in diameter. The breaking weight was 25387 lbs., and equation (24) gives Q.S=25490 lbs., where S is the area of the cross-section. The formula for columns fixed at one end and free to turn about the other end may be derived from eq. (23) by substituting $\frac{2l}{3}$ for l; so that for columns fixed at one end

$$Q=\frac{49000}{1+\frac{1}{14400}\left(\frac{l}{\rho}\right)^2}$$

The general formulæ for wrought iron are then, for columns:—

Free to turn about both ends

$$Q=\frac{49000}{1+\frac{1}{6400}\left(\frac{l}{\rho}\right)^2}.$$

Fixed at both ends

$$Q=\frac{49000}{1+\frac{1}{25600}\left(\frac{l}{\rho}\right)^2}.$$

Fixed at one end

$$Q=\frac{49000}{1+\frac{1}{14400}\left(\frac{l}{\rho}\right)^2}.$$

Flat at both ends

$$Q=\frac{36000}{1+\frac{1}{36000}\left(\frac{l}{\rho}\right)^2}.$$

WOODEN COLUMNS.

Experiments on wooden columns have been limited in number, and the available experimental data on the strength of pine columns seem insufficient to determine a satisfactory formula. A few experiments by Lemandé on square oak columns with flat ends, which are quoted by Hodgkinson in the *Phil. Trans.*, 1840, and the experiments made by Hodgkinson on square columns of Dantzic oak with flat ends are here used to derive formulae for the strength of oak columns. The crushing strength of the oak used in Lemandé's experiments was 6336 lbs. per square inch. When this value is given to f in the general equation

$$Q=\frac{f}{1+a\left(\frac{l}{\rho}\right)^2}=\frac{f}{1+12a\left(\frac{l}{h}\right)^2},$$

where h is the side of the square, the corresponding values of $12a$ in the table are seen to decrease as $\frac{l}{h}$ increases, $12a$ being more than twice as great for $\frac{l}{h}=6$ as for $\frac{l}{h}=36$. When $12a=\frac{1}{400}$, since f increases as $\frac{l}{h}$ increases, $12a$ is two large; and when $12a=\frac{1}{700}$, since f decreases as $\frac{l}{h}$ increases, $12a$ is too small. So that $12a$ has some value between $\frac{1}{400}$ and $\frac{1}{700}$ for which value f is constant. Owing to the small number of experiments and to the anomalies in some of the results the value of $12a$ can be only approximately determined; and $\frac{1}{550}$ seems to be near the truth. The mean value of f corresponding to $12a=\frac{1}{550}$ is, in round numbers, 5600; and the formula for square oak columns with flat ends is

$$Q=\frac{5600}{1+\frac{1}{550}\left(\frac{l}{h}\right)^2} \quad . \quad . \quad . \quad (25)$$

The general formula for oak columns with flat ends is, therefore,

$$Q=\frac{5600}{1+\frac{1}{6600}\left(\frac{l}{\rho}\right)^2}$$

where ρ is the radius of gyration of the transverse section. The crushing strength of the Dantzic oak used by Hodgkinson in his experiments was 7731 lbs. per square inch. When $12a=$

TABLE IV.

Lemande's Experiments.									Dantzic Oak.		
l	h	$\frac{l}{h}$	$12a$ when $f=6336$.	Values of Q. S. By experim't.	Values of Q. S. By eq. (25)	f when $12a=\frac{1}{400}$	f when $12a=\frac{1}{550}$	f when $12a=\frac{1}{700}$	$\frac{l}{h}$	f when $12a=\frac{1}{550}$	f when $12a=\frac{1}{1000}$
25.5	4.25	6.0	.00530	96001	94980	5793	5660	5586	16.9	6321	5501
25.5	3.18	8.02	.00400	50958	50698	5851	5629	5498	17.3	6999	6065
25.5	2.13	12.0	.00330	19495	20050	5864	5443	5197	27.4	5888	5280
51.0	3.18	16.03	.00300	36223	38547	5885	5258	4896	30.7	9013	6808
76.5	4.25	18.0	.00270	60783	63660	6091	5347	4923	34.6	9403	6898
76.5	3.18	24.0	.00196	29961	27590	7247	6079	5401	45.2	7575	5233
51.0	2.13	23.99	.00224	12523	12370	6753	5667	5047			
76.5	2.13	35.98	.00210	7769	7547	7282	5765	4897		Mean	5964
					Mean value,		5606				

$\frac{1}{6000}$, since f increases as $\frac{l}{h}$ increases, $12a$ is too large. When $12a=\frac{1}{1000}$ the mean value of f is nearly 5900, and the variations in the value of f seem to be independent of $\frac{l}{h}$; so that the formula for square columns of Dantzic oak with flat ends is

$$Q=\frac{5900}{1+\frac{1}{1000}\left(\frac{l}{h}\right)^2}.$$

The general formula for columns of Dantzic oak is, therefore,

$$Q=\frac{5900}{1+\frac{1}{12000}\left(\frac{l}{\rho}\right)^2}$$

ρ being the least radius of gyration of the transverse section.

Hodgkinson's experiments have been used to deduce the formulæ for iron because they are the most accurate and extensive that have yet been made; and also in offering an interpretation of the values given to f by Gordon it seemed best to use the same data that Gordon did.

The experiments on wrought-iron columns of the full size used in practice, and embracing all ordinary forms, which were made under the supervision of G. Bouscaren, Consulting and Principal Engineer of the Cincinnati Southern Railway, and which are contained in the report published by Thos. D. Lovett in 1875, while of great practical value are not suitable to form the basis of general formulae. The columns were placed horizontally, and pressure applied with a hydraulic press. Mr. Bouscaren is authority for the statements,—that no allowance was made for friction between the parts of the press; that in some of the experiments made in winter glycerine, instead of water, was used in the press; and that the experiments were mostly made in close proximity to heavy machinery, which kept the columns in constant vibration. The experiments have accomplished their object in establishing the correctness of Gordon's formulae when applied to built columns. Also from the results of these experiments Mr. Bouscaren has been led to incorporate in his specifications for bridges, the rule that the thickness of the metal in a column shall not be less than one-thirtieth of the horizontal distance, nor than one-sixteenth of the vertical distance between consecutive rivets. It was found when columns were proportioned according to this rule that the plates buckled at the same time that the column bent, and that hence the maximum efficiency of the material was secured.

HODGKINSON'S FORMULAE.

Although Hodgkinson has proposed formulae for wrought-iron and wooden columns, similar to his formulae for cast-iron columns, the latter alone have ever been much used. The general form of Euler's formulæ, given in equations (4) and (7), is $P=C\frac{I}{l^2}$; C being a constant depending on the method of fixing the ends, and I the moment of inertia of the transverse section of the column. For cylindrical columns of diameter d this equation becomes $P=\frac{\pi C}{64}\cdot\frac{d^4}{l^2}$. Hodgkinson, accepting the formulae proposed by Euler as theoretically correct, assumed the value of the breaking weight for solid cylindrical columns to be given by the equation $P=C\frac{d^m}{l^n}$, where C, m, and n are constants to be determined by experiment. In the *Phil. Trans.*, 1840, Hodgkinson has discussed his formulae for cast-iron columns so exhaustively that nothing further is needed to clearly understand them. The assumption made by him that the strength of hollow cylindrical columns is equal to the difference between the strength of solid columns having diameters equal to the external and internal diameters of the hollow column should be noticed. The general form of Gordon's formula,

$$P=Q.S=\frac{f\cdot S}{1+a'\left(\frac{l}{\rho}\right)^2}$$

has been shown to give results agreeing with experiments on both iron and wood, when f and a' have proper values, and the experiments on built columns made by Bouscaren show that this formula is *generally* true. Let d_1 be the internal

and d_2 the external diameters of a hollow column; and S_1 and S_2 the areas of the corresponding circles; then if the assumption made by Hodgkinson be true,

$$\frac{f(S_2-S_1)}{1+a\frac{l^2}{d_1^2+d_2^2}}=\frac{f.S_2}{1+a\frac{l^2}{d_2^2}}-\frac{f.S_1}{1+a\frac{l^2}{d_1^2}}$$

$$\therefore \frac{(S_2-S_1)(d_2^2+d_1^2)}{d_1^2+d_2^2+al^2}=\frac{S_2d_2^2}{d_2^2+al^2}-\frac{S_1d_1^2}{d_1^2+al^2}$$

substitute for S_1 and S_2 their values in terms of the diameters, then

$$\frac{d_2^4-d_1^4}{d_1^2+d_2^2+al^2}=\frac{d_2^4}{d_2^2+al^2}-\frac{d_1^4}{d_1^2+al^2}.$$

Since the right hand member of this equation is greater than the left, it follows that a hollow column is not as strong as the difference between the strengths of two solid columns. If the above equation be reduced to a common denominator it reduces to $0=al^2.d_1^2d_2^2(d_2+d_1)(d_2-d_1)$ $\therefore$ $d_2=d_1$, which is impossible. Hodgkinson's formulae for cylindrical cast-iron columns are

$P=14.9\frac{d^{3.6}}{l^{1.7}}$ tons, for solid columns with rounded ends.

$P=44.16\frac{d^{3.6}}{l^{1.7}}$ tons, for solid columns with flat ends.

$P=13\frac{d_2^{3.6}-d_1^{3.6}}{l^{1.7}}$ tons, for hollow columns with rounded ends.

$P=44.3\frac{d_2^6-d_1^6}{l^{1.7}}$ tons, for hollow columns with flat ends.

The coefficient for columns with round ends is a little less for hollow than for solid columns, as it should be; but for columns for flat ends the coefficient is greater for hollow than for solid columns. These coefficients are the mean values computed from many experiments, and the coefficient for hollow columns with flat ends is the mean not only of the values of the coefficient for columns with flat ends, but also for columns with discs on the ends, which accounts for its greater value.

The conclusion that the strength of a hollow cylindrical column is less than the difference between the strengths of two solid columns having diameters equal to the internal and external diameters of the hollow column may be reached independently of Gordon's formula. According to the general theory of flexure, a longitudinal shearing stress is induced when a girder is bent. In illustration of this, Rankine adduces the familiar fact that a pile of boards of equal lengths will slide upon one another when bent, and the ends will not then lie in a plane. It follows immediately from this principle that the strength of a hollow column will be less than the difference between the strengths of two solid columns by an amount at least equal to the shearing stress which would be produced over the inner surface if the column were solid.

SUBURBAN HOUSE DRAINAGE AND WATER SUPPLY.

By ROBERT VAWSER, C. E.

From "The Architect."

I PROPOSE to describe very briefly the drainage and water supply at a large detached mansion in Cheshire, the residence of about forty or fifty persons. An outbreak of fever was the immediate cause for undertaking the works, and for the same reason the remedy was as thorough and complete as possible, and nothing that prudence could suggest to prevent a recurrence of the outbreak was neglected.

An inspection of the premises revealed many serious defects.

Some of the drains were brick circular drains; some had inverts and covers of stone with brick sides; they were generally 3 feet in diameter, or $3'0''\times2'6''$ square, and had been altered and extended from time to time, and were irregular in direction, size, and depth: they were nearly filled with accumulations of sewage sediment, and in many places were under the buildings. The waste pipes and several grids in the larder, kitchen, and cellar were untrapped; the floors were honey-combed

with rats, and there was practically no obstacle to the uncontrolled escape of sewer gas into the living apartments.

Most of the water closets were new and in good working order; their soil pipes were ventilated at the top by 2-inch pipes, but they communicated direct with the sewer, as also did the waste pipes from the wash bowl, urinal and housemaids' closets; these latter had lead syphon traps under the basins.

In designing the new drains, very great care was taken to prevent the escape of sewer gas into the house, and wherever a drain approached the house its continuity was broken by a water trap and ventilator. All the old drains were taken up, the mud removed from under the house, and the space made good with clean earth or concrete; the rat-runs and useless drains were destroyed.

The clean water draining from the cellars, together with the overflow from cisterns and tanks, has been taken off by a special drain; the sewage is collected separately into 9-inch stoneware pipes, and purified on a small plot of land carefully underdrained and planted with comfrey, a very prolific plant, well suited for sewage cultivation, and as food for cattle.

Near the center of the main buildings three water closets, a wash bowl, a urinal, and three sink waste pipes discharge at the same place; these have been conducted into an "Edinburgh trap," the object of which is to stop the direct flow of sewer gas, by a water trap, and to admit fresh air at the base of the soil and waste pipes; the ventilation of these pipes is further ensured by continuing them at their full size to the roof. The drains have been ventilated by some of the rain water spouts, and by special ventilators in open places. The waste pipes from kitchen, laundry, &c., have been taken through the outside wall, and discharge on the top of trapped gullies; many useless grids both inside and outside the premises have been dispensed with.

The water supply was found to be very inferior; it consisted of surface water collected on cultivated land, and was otherwise polluted; it was consequently abandoned, and a better supply sought elsewhere.

The mansion is situated over the red marl in which the salt deposits of Cheshire are found; the surface is covered with a great thickness of drift sand and gravel. It occupies an elevated position, and is surrounded by a considerable area of table land, which upon examination was found to contain an abundant supply of pure water fit for every domestic purpose; a cutting having been made in the slope leading from the table land, a flow of nine *gallons* per minute was quickly yielded, and it was ascertained this could be increased to almost any reasonable extent.

The level of the cutting yielding this water is so much above the valley contiguous to it, that it was found practicable to raise all the water required for the use of the mansion by hydraulic power: this is effected by one of Douglas's hydraulic rams, placed in the valley about 15 feet below the spring; the ram is 80 feet below the tank on the roof of the mansion; it has required no attention or repairs, and has supplied a continuous flow of water, at the rate of 1,000 gallons per day, for the last six months.

The roof water from a very large area of slates and lead is likewise collected, affording an ample supply for every purpose.

It was at first expected steam or horse power would have been required to pump from some distant source, and the discovery of a copious supply so near at hand was made almost by chance, the application of this discovery may possibly sometimes prove the solution of one great difficulty in rural districts, viz: the water supply to small communities. Parliament fixes the value of a supply of water to a cottage at 2*d.* per week, which will shortly be increased to 3*d.* per week. It is difficult to work within this limit, but an apparatus, such as described, would supply a group of cottages or a mansion at a very trifling expense.

Its great merit is that no permanent expense is incurred, the apparatus really requires no attention, and will work continuously if let alone.

The Local Government Board urgently exhorts local authorities to improve their supplies of water, but the prices legally chargeable to consumers are seldom remunerative if costly engineering undertakings are forced upon small com-

munities. The water resources of the country have lately been prominently discussed, and the opinion appears to prevail, that relief must be sought in the development of local resources, rather than in colossal national undertakings.

One reason for presenting this paper is to direct special attention to the question of house drainage, a subject often neglected by the engineer, who not unfrequently devotes his entire attention to the main and outfall works, and neglects minute details. It should never be forgotten that however important and interesting the outfall and main drainage may be, they form but a small portion of the ultimate cost; and the health of the community, which is the sole object of all sewerage undertakings, is influenced less by them than by details that are often overlooked.

People living in cottages are generally less exposed to infection from sanitary defects than those in houses of the better class, where every water closet, bath, and entrapped cellar drain, is a source of constant danger. The best and only security against danger from these is a continuous current of fresh air through the soil and waste pipes; a 1-inch or 2-inch ventilator at the top of the soil pipe is practically useless; every soil pipe should be quite open at the top, and have an equal inlet for fresh air near the bottom, and should be kept outside the house if possible.

The cellar drain when connected with a common sewer should have a water trap and ventilator just outside the building, in addition to the gully within, and the slopstone waste pipe should not be laid direct to the sewer, but to the top of a trapped gully outside the building.

It is most important that the execution or workmanship of all drains or other sanitary appliances should be of the best possible; on no account ought works of this nature to be left to the discretion of the least unintelligent workman, as is too often the case: care is necessary to ensure uniform and sufficient gradients; this is quite as important in small as in large works, and should be jealously watched; every pipe should be ranged or boned in, and laid at a gradient proportioned to the size of the pipe and the flow of sewage along it. As a general rule, house drains are too large; a 9-inch pipe is sufficient for almost the largest mansion, or a village say of 1,000 inhabitants, provided the gradients are good and surface water excluded from the drains.

An endeavor has been made to fulfill these conditions in the works forming the principal subject of this paper. The details can hardly be described at greater length without the aid of diagrams.

If we consider the condition in which the mansion was found, and in which other residences are known to be, it becomes a matter for reflection whether the system of inspection by local authorities is carried far enough. In new buildings disgraceful blunders are sometimes perpetrated through ignorance or neglect; and we have an accumulation of such blunders as a legacy from an age when sanitary measures obtained but little attention. The condition of the new offices of the Local Government Board at Whitehall may be taken as an instance of the former, and Marlborough House of the latter class.

NEW MOUNTAIN GUNS.—A complete battery of six guns on a novel principle have just been completed at the Royal Gun Factories, Woolwich, and will be issued for service. They are called "mountain guns," but instead of weighing merely 200 lbs., like the "mountain gun" used in Abyssinia and Zululand, they will weigh 400 lbs. each. As, however, an essential condition of mountain artillery is that every part of it shall be carried on the backs of mules, these guns are made in two pieces, screwed together, and strengthened at the joint by a third piece in the shape of a ring or collar. The breech end of the gun when disjointed weighs 200 lbs., and the barrel with collar amounts to about the same weight, which is regarded as a fair burden for a mule over hilly country. These guns, like their smaller namesakes, are of the small calibre adopted for 7-pounder projectiles, but their greater length and weight enable them to do much more effective work. They have been made from a design by Sir William Armstrong.

THE ACOUSTIC PROPERTIES OF BUILDINGS.

From "The Architect."

"THE Construction of Buildings in Relation to Sound" formed the subject of an interesting paper, which was read at the meeting of the Musical Association.

Mr. Cecil C. Saunders, the author, said that with the growing appreciation of and the desire to hear good music, has come in a great measure the modern importance of the subject. The construction of buildings of the class for enabling large numbers of persons, at once, to hear vocal and instrumental music to the best advantage might be considered under six primary heads or divisions, viz., size, shape, proportion, situation of the singer or orchestra, materials employed, and the bearing of all these upon the kind of music to be performed. It was difficult to find a building equally well adapted for the hearing by a large number of both slow music and rapid. It would be obvious that the size of a concert-room depended more upon the amount of disposable funds than anything else, and equally obvious that a small room would not be so liable to acoustical defects as a large one. It should be remembered that every listener must have from five to six square feet in area; and as music should be good, and good music should be heard in comfort, six square feet was not at all too much to give to each seat, including passages between one part and another. This would give an area of 6,000 square feet for 1,000 auditors, or 30,000 square feet for 5,000, which, he thought, was almost the greatest number that could reasonably be expected to hear good music well. The shape of a concert-hall was too frequently subservient to that of the plot of ground on which it was to be placed; and here it was that the architect had to make use of all his ingenuity, and the utmost fertility of his resources, in order to obtain the largest amount of accommodation upon the site at his disposal. The usual shape of a concert-hall was a rather long rectangle; if for a large audience, galleries were introduced at the end, and perhaps at the sides, the orchestra being placed opposite the end gallery. This form had its advantages, but for a large hall it had serious drawbacks. If it be very long, a large number of the audience were at so great a distance from the performers that the waves of sound, being interrupted, did not reach the more distant listeners with anything like their initial crispness and force. If, on the other hand, the room was very broad, there was a tendency to echo, as the sound which traveled direct to the listener from the orchestra came to him also from the side walls by a more circuitous route, giving, if not an obvious echo, an indefiniteness and want of decision throughout. This of course would not be the same in all parts of the hall. The height of the room had also to be considered, bearing as it did directly upon its acoustical properties, and the height could only be satisfactorily considered in reference to the contour of the ceiling. A circular room had great disadvantages, particularly when associated with a high and vaulted ceiling. One of the most successful places for hearing that he knew of, which approached to a circular shape, was Surrey Chapel, which had sixteen equal sides and a gallery all round, and was built to accommodate 1,400 persons. It had windows round it, both above and below the gallery; the roof over the center portion was hemispherical, with a small lantern at the apex. This chapel was almost free from echo, but it required a powerful voice to fill it.

Mr. Saunders stated that great height in a concert-room appeared to be disadvantageous to the hearers, and suggested that, having due regard to proper and perfect ventilation, it should not be higher than was necessary. Writing upon concert-rooms, Mr. Statham said "as a general rule, music cannot be really enjoyed in rooms above a certain limit of size, certainly not music requiring delicacy of execution and expression. It may be doubted whether it is possible to enable more than 2,000 persons at the outside to hear an orchestral symphony

with full enjoyment and realization of the intended effect." With all due respect to Mr. Statham, he (Mr. Saunders) felt very much inclined to combat his suggestion, and to say that he had little doubt but that 5,000 might, in a properly-constructed building, hear an orchestral symphony with full enjoyment and appreciation of the most delicate points. In considering the size of concert-rooms, the first question that arose was, How far the sound designed to be heard would travel? By far the greater portion of sound, so to speak, went upwards into the air, and but a small part was directed towards the hearing level. A resonant wall or sound reflector, placed anywhere within the limits of the voice, would have the effect of reinforcing the sound between it and the speaker or beyond him to some extent. As to the extraordinary modifying influence upon the intensity of sound which was produced by light, this, he confessed, he was unable to account for or to explain, but thought that when the dynamic force of light was better understood, they would be able to obtain a scientific reason for this remarkable fact. The height at which a ceiling should be placed depended upon the necessity for ventilation and other matters, but, as far as acoustics were concerned, a ceiling should be as low as practicable if the aim be to carry sound far in a horizontal direction. Every foot of additional height lessened the horizontal distance to which the sound could be carried, and consequently the number of possible hearers. The position of the performers on the orchestra ought to engage their attention, as, although little regard was bestowed upon it usually, a great deal of the possible successfulness of a concert-hall was attributable to it.

Mr. Saunders then entered into a detailed statement of what he called "a model concert-hall," which, he stated, should be a square room with rounded corners. In defiance of preconceived notions of symmetry, he proposed to put the orchestra in one corner; it should be capable of seating 700 performers, and of course the orchestra seats must rise tier above tier up into the angle of the building. He would have an organ, and put the greater part of it beneath the orchestra, and have it only visible above so as to permit the ceiling to be as low as possible in order that the voices of the tenors and basses might be diffused perfectly over the whole building. Light for the orchestra and chorus should be obtained from a sun-burner or electric light in the extreme angle of the ceiling, so shaded as to be of the utmost service to the performers, but unseen by the audience. The light would be thrown from behind the chorus and orchestra so as to give them the best possible advantage from it. Ventilation should also be gained by the same means, and by peforation in the ceiling, ribs, and cornice. By placing the orchestra in the angle of the building, the difficulties that arose from its position were obviated, either at the end of a long hall or in the center of the side of a wide one. The auditorium to seat 5,000 persons might have a circular arrangement so as to give everyone a direct view, and therefore a better hearing of the performers. The circles should be described from a point near the center of the orchestra, and the levels of seats should be so arranged as that those sitting in the rear should have no difficulty in seeing and hearing over the heads of those in front, the seats in the extreme angle opposite to the organ being almost as high as the top of the orchestra. Under this arrangement, the sound traveling along, or rather being deflected at a very obtuse angle by the ceiling, would reach those at the greatest distance as clearly as it would those nearer to the performers. As to the materials, great care was necessary in their choice. He would recommend wood for the ceiling, the boards being carefully and accurately tongued and glued together, so that each bay would be one large sounding-board. Plastering, in the ordinary sense, was the worst possible ceiling, and was a non-conductor of sound. Zinc would be nearly as cheap as wood, and perhaps more efficacious. The ceiling might be divided by circular and radial beams, perforated for ventilation. As to the walls and their covering, he believed looking-glasses to be good for this purpose, as they reflected sound, but they should not be bedded in flannel, as was usual; they should be placed on the walls adjoining the orchestra. With regard to the remainder of the walls, he would recommend boarding or cement.

Stone would be better, but its great cost was almost prohibitive. If there was the probability of a sparse audience, heavy curtains should be suspended, wherever necessary, from hooks in the ceiling prepared for the purpose.

A NEW METALLIC COMPOUND.

By GRANVILLE COLE, Ph.D.

From "Engineering."

THE paper which I am about to read this evening affords me the privilege of appearing, for the first time, before a meeting of the members of the Society of Arts, and I hope you will grant me your indulgence for any shortcomings which may attend this, my first appearance as a public lecturer in England.

The subject of the paper is the discovery of a metallic compound, which I shall prove to you is new, and I shall endeavor further to set forth a few facts, attested by experiments, in respect of its nature. I am duly impressed with the very technical character of my subject, and the tendency there must be, in dealing with it, towards a certain dryness in my remarks. But, while I trust that many of the data will appeal with special interest to engineers and other practical men, I still hope to arrest your attention by showing you to how many artistic and industrial purposes this new metallic compound may be put. In the first place it will be right to give a brief account of the metal.

Nearly a year ago, Mr. J. Berger Spence discovered that the sulphides of metals, combined with molten sulphur, formed a liquid. This liquid, on cooling, became a solid homogeneous mass, possessing great tenacity, and having a peculiar dark grey—almost a black—color. Nearly every metallic sulphide which is known combines, as experiments have proved, with an excess of sulphur, and curiously enough, nearly all these combinations have the same properties. The combination, of which I have specimens here for inspection, consists of an ore of iron pyrites containing both lead and zinc sulphides.

Examining the metal from a chemical point of view, I may state, briefly, that it is a chemical compound belonging to that class known as thiates, or sulphur sulphides.

Dr. Hodgkinson, chemical demonstrator at the Science Schools, South Kensington, has kindly sent me the following facts. I cannot do better than to quote his letter on the subject:

"It appears to be the easiest thing in the world to obtain a homogeneous casting with it. Specific gravities of portions sent gave 3.3743 to 3.7036 (reduced to 0° C).

"When finely powdered, it is acted upon slowly by concentrated HCl. and NO^3 HO in the cold; in large lumps, little or no action takes place. As yet I have not been able to determine the expansion equivalent accurately; it would appear, however, to be small. The fracture is not conchoidal, as might perhaps have been expected, but somewhat like that of cast iron.

"I have not had time to try many 'utilization experiments' on the substance, but I have no doubt it would be exceedingly useful in the laboratory, even, for instance, for making the air-tight connections between glass tubes by means of caoutchouc, and a water or mercury jacket, where rigidity is no disadvantage; the fusing point is so convenient, about 340°, that it may be run into the outer tube on to the caoutchouc, which it grips, on cooling, like a vise, and makes perfectly tight.

"I don't know what you may call the material, but should think, as it seems to be more than a mere mixture, 'ferric thiate' would not be a bad or inappropriate name."

I propose, this evening, to illustrate, by experiments, such as are possible at a lecture, some of the properties of the metal. I will begin by giving you a short summary of its peculiarities, and

its advantages over those of other metals or metallic compounds.

1. It has a comparatively low melting point, viz., 320° Fahr., or rather more than 100° above the temperature of boiling water. Here, then, we have in its favor the small amount of fuel needful to supply the necessary heat for reducing the metal to a condition for use.

2. It expands on cooling, a property not shared by the majority of other metals or metallic compounds. I believe that type metal and bismuth are two exceptions. Later on, I think I shall convince you that, for an operation like the joining of gas and water pipes, this expanding property is one of great importance.

3. It claims to resist atmospheric or climatic influences, as compared with bronze and marble. I noticed only a few days ago how the statues in bronze, on the Holborn Viaduct, had been affected by our London fogs. And I have evidence to produce in the direction of showing the imperviousness of the metal to such degrading influences.

4. As compared with other metals of metallic compounds its resistance to acids, used commercially, to alkalies, and to water, is certainly superior.

5. A smooth surface of this metal or metallic compound, now known commercially as Spence's metal, takes a very high polish. I will illustrate this to you by casting some of this molten metal on to a surface of glass.

It may, perhaps, be interesting to my hearers to learn the manner in which Mr. Spence first thought of utilizing this metal for works of art. In order to obtain a perfectly smooth surface, he had been running molten metal on to a piece of glass as I have just done. But before doing so, he had chanced to touch the glass, and had left the marks of the pores of the skin of his fingers upon it. On removing the metal, these marks were found to be reproduced, and so indelibly that they did not disappear on polishing the surface metal. This led Mr. Spence to try to cast the metal in a mould; and although at present no artistic work of high order has yet been reproduced, yet I venture to think that enough has been done to justify the expectation that, in a short time, standard works of both ancient and modern art may be successfully and usefully reproduced. Various colors, such as the green patina of bronze, the dark blue hue of steel, and the appearance of silver and gold, have already been obtained. Experiments are now in progress, which give promise of enabling those who adopt this metallic compound for such uses, to reproduce metallic works in their original colors.

I have here a casting that was made from a nickel-plate engraving; every line, however minute, has been reproduced in Spence's metal. Experiments are now being carried on to test the adaptability of the metal for printing and stereotyping purposes, but they are not complete, so I refrain from giving you any facts about them.

Besides this, experimental castings have been made of various medallions and busts; notably, this large bust of her Majesty the Queen. The metal in this case has not subsequently been treated in any way beyond being polished with a cloth. The metal can be cast into almost any material used for moulds.

Mr. Spence has succeeded in obtaining casts from metal moulds, plaster moulds, and even from gelatine moulds. These last are probably the first metallic castings produced from gelatine moulds. Spence's metal being almost a non-conductor of heat, cools so rapidly in the gelatine mould that it yields a perfect impression before the form of the mould is destroyed, and if the gelatine be allowed to remain on the metal till cold, it remodels itself ready for the next casting. It is, therefore, hoped that an additional process has been secured, by which the most undercut objects may be reproduced successfully and easily.

The advantages which Spence's metal possesses over other materials used for artistic productions may be summarized under three heads, viz: 1. Cheapness. 2. Facility of working. 3. Resistance to climatic influences.

CHEAPNESS.

As compared with lead, which is one of the cheapest of metals, it is one-third the weight; and, whereas the average cost of lead for the last ten years has been nearly £18 a ton, Spence's metal only costs £15. A ton of Spence's metal

being three times the amount in bulk of that of a ton of lead, it is available for three times the amount of work. It may, therefore, be considered to be nearly a quarter of the price of lead, and, consequently, very considerably less than that of bronze.

FACILITY OF WORKING.

Its melting point being very low, it can be very easily prepared for pouring into a mould, and its property of expanding, when cooling, causes it to take such a perfect impression, that the cast requires very little chasing after. In respect of a gelatine mould, which can cover a considerable surface of work without joints, such as one has to make in plaster piece moulding, the metal cast obtained from such a mould would require no chasing whatever.

RESISTANCE TO THE ATMOSPHERE.

With regard to its resistance to climatic influences, experiments have been conducted in this direction with complete success. A polished surface of the metal has been exposed for six months in all weathers, without showing the least change.

Mr. Wood, the secretary of this Society, has had a medallion, which I sent him a month ago, exposed to all the recent fogs and frosts, on the outside of this building. You can judge and see for yourselves how well it has stood this test.

Not to confine myself to his test alone, I have here another medallion of this metal, which Mr. Wood tells me has been left for the same period in aqua-regia, one of the strongest acids known. You see how little effect the acid has had on the surface of the metal. I believe that no work of art in any other substance would bear this test without suffering. I will here endeavor to show you the effect the same acid has on marble or bronze. I venture to think that if Spence's metal has resisted this acid for a month, it ought certainly to be able to resist the climate of London for a very much longer period. I, therefore, beg to submit that this metal, if skilled labor is brought to bear on it, ought to be of great value for decorative purposes, both internal and external.

I will endeavor now to point out to you the uses to which this metal may be applied for industrial purposes. And I propose to divide these purposes under three heads: 1. Gas and water works. 2. Chemical works. 3. Miscellaneous.

GAS AND WATER WORKS.

As practice is better than theory, I will simply relate, as best I can, those experiments which have been tried at the South Metropolitan Gas Works. Experiments, under the direction of Mr. Livesey, were made some weeks back; two pipes were joined by this metal in much less time than would have been taken had lead been employed. The pipes, after having been joined, were tested under pressure but no leakage was found.

METHOD OF JOINING PIPES WITH LEAD.

In order to show the especial advantages this metal has over lead, it will be as well here, if I endeavor to tell you how gas or water pipes are joined when lead is used. The pipes having been laid together, the joint is packed with yarn; clay is then laid round the exterior of the joint, and the molten lead is run in. Unfortunately, lead possesses the property of contracting on cooling. The leaden joint has, therefore, to be "caulked," or, as it is called in the north, staved. This caulking, or staving, means wedging the lead into the joint, in order to obtain a perfectly tight joint. This caulking naturally occupies considerable time, and necessitates excavation, in order to allow the men to work all round the pipes.

Excavation and caulking are both rendered unnecessary by the use of Spence's metal. The pipes have only to be laid together, and after the yarn has been forced into the joint and the clay placed, the liquid metal is run into the joint, the clay is removed, and the joint is finished. The metal does not splash in running into the mould, thus avoiding a great source of waste of material, and danger to workmen.

Experiments were also tried to test the metal joints in the event of subsidence of the ground. Four lengths of 9 ft. piping, 6 inch diameter, were joined with the metal, and supported on trestles.

After the metal had set, which it did in a few minutes, the center supports were knocked away, leaving only the two end ones. The 36-ft. length of piping sank 7 inches, without showing, even after pressure, a leakage.

These experiments were so satisfactory, that the South Metropolitan Company have adopted the metal, and are now laying their pipes with it. Mr. Livesey, the chief engineer, in writing on the subject to Mr. Spence, says: "We have now only the test of time, and that, I think, we may take the risk of." Others of the London gas works, and a very large number of provincial gas works, are adopting it.

In the same way, it will be useful for water works. Mr. Hope, who undertook some experiments in Scotland, reports that at the Edinburgh Water Works two pipes were joined and subjected to a pressure of 400 ft. of water, which was as much as they could get on without the joint showing any leakage. This is the greatest pressure which we have as yet been able to put it to; so what it will actually bear, I am not at present in a position to say.

From a sanitary point of view, as water has no action on the metal, it would be extremely valuable for cisterns, instead of iron or lead. Being almost a non-conductor of cold, pipes might be lined with it to prevent the water from freezing.

USES TO CHEMICAL WORKS.

The metal being less acted upon by acids than other metals, it may also be of service to chemical manufacturers. I refer especially to sulphuric acid, which is the most extensively used of all acids in commerce. Lead has, up to the present, been used for sulphuric acid tanks. I have myself tested the metal with sulphuric acid, and its action is almost imperceptible. The one objection to the use of this metal in this case is its low fusing point, but when acids have only to be used up to a certain temperature, say 200° Fahr., I venture to predict a large field for its use.

Besides the uses I have thus briefly and, I am afraid, somewhat imperfectly set before you, there are many others to which the metal may be applied, for instance, joining iron to stone or wood, the tensile strain of the metal being from 650 lbs. to the square inch five minutes after setting. For joining railings to stone it would answer equally as well as lead, and cost very much less; also for coating the holds of ships. I have been told that an Act of Parliament has been passed by which builders are compelled, if the district surveyors desire, to cover the walls of houses after they are built 2 ft. out of the ground, with some material to prevent the damp from rising. It seems to me that Spence's metal is peculiarly adapted for this purpose.

I will illustrate to you some of the other uses to which this metal may be put. For hermetically sealing bottles; for covering cloth; for covering parcels that are being sent out to hot climates, thus obviating the use of lined boxes; for preserving fruit, or other articles of consumption; and I may state that experiments on a large scale are still being carried on at Mr. Spence's works, Belvedere, Kent.

I feel sure we have not yet come to the end of all the uses this Spence's metal may be put to, but I trust that I have shown you sufficient to induce you and others who may be interested in this discovery to make further investigations. If my paper is somewhat shorter than is usual, it is to some extent owing to my hesitation to make any statement which either Mr. Spence or I have not verified by actual experiment ourselves. I have already shown you a few of them, viz., casting on glass, casting an engraving, casting in metal moulds, casting in plaster moulds, casting in gelatine, resistance to atmospheric action, resistance to acids, resistance to acids as compared to bronze or marble, and uses in gas and water works. In conclusion, I express a hope that I have established the proposition with which I started, and I trust you are satisfied that this Spence's metal is a discovery which has a prospect of much utility to the fine and industrial arts, and that I have been justified in bringing it before the attention of the members of the Society.

DYNAMO-ELECTRIC MACHINES.

From "Engineering."

II.

We are now prepared to discuss the various systems of winding a Siemens armature. The actual system adopted by Von Alteneck and Siemens is a little complicated. In attempting to explain its nature, M. Breguet devised a simpler system so closely resembling it that he at first thought it identical. He took a single stout wire and bent it up in the manner represented in Fig. 12, the two ends being soldered to one another, and

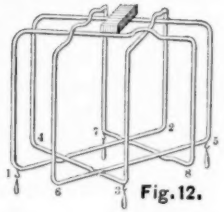


Fig. 12.

the separate bends so insulated as not to touch one another where they cross. Four little contact pieces were added at the corners 1, 3, 5 and 7, to dip into mercury cups like those of the preceding apparatus, but with quadrantal sectors, as in Fig. 10. Now here the whole current obviously traverses each branch of the conductor, and the rotation will take place with more than redoubled energy;

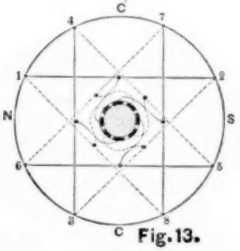


Fig. 13.

for the impulses will last during a whole quarter of a revolution, and there will always be two wires attracted, and two repelled by each pole of the magnet. The same system is represented diagrammatically in Fig. 13, where, however, a metallic collar slit into eight portions is supposed to replace the little contact pieces used for dipping into mercury cups. Of course more than eight vertical wires might be employed. Any regular polygon having an even number of sides would answer; but the octagon with star-like points is very simple and effective, and answers all purposes. As before, each single wire of the simple experimental apparatus may be replaced by a coil of many turns; and the whole may be wound upon a longitudinal cylinder or core.

The actual method of winding up the bobbin of a Siemens generator — the method invented by Herr von Alteneck — is represented in a similar diagram in Fig. 14; from which it will be seen that the arrangement adopted has sixteen

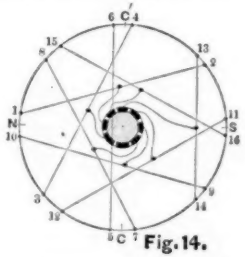


Fig. 14.

vertical conductors, and that it is an unsymmetrical one.

Curiously enough, a German engineer, Her Frölich, who, like M. Breguet, intended to describe the Siemens (or Von Alteneck) armature, discovered another system of winding up the wires, which is shown in diagram in Fig. 15. Here also there are sixteen vertical conductors arranged in pairs at the point of a regular octagon, and crossing the octagon by the diagonals at one end of the armature and by long chords crossing in the form of an eight-pointed star at the other.

There are, in fact, a large variety of ways of winding that coils upon a longitudinal armature, of which that adopted by Siemens is one, and not the best one.

M. Breguet says he has found no fewer than eight. Of these there is one which

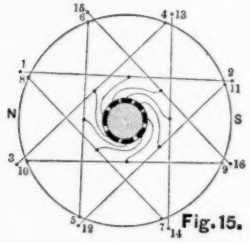


Fig. 15.

appears to be better than all the others. It is represented in Fig. 16. Its superiority consists in requiring the employment of a shorter length of wire to attain the same effects; which of course means not only a reduction of first cost, but a saving in the wasteful heating effects of

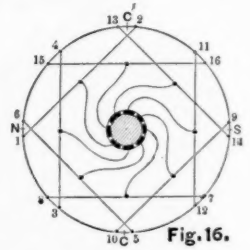


Fig. 16.

internal resistance. In this system the portions of the coils which cross the ends of the armature to unite the sixteen vertical wires cross the octagon along short chords. As these end portions of the coils contribute little or nothing to the effective work of the motor or generator it is a clear advantage that they should be as short as possible. M. Breguet has given the following as a Table of the proportional lengths of wire necessary to make up end portions of equal sized armatures on the four systems:

System of Herr Frölich (Fig. 15).....	30.8
" Von Alteneck and Siemens (Fig. 14).....	30.5
System devised by M. Breguet (Fig. 13)..	28.4
" " " (Fig. 16)..	26.0

From which it appears that the last described arrangement is superior to all the others. Mr. Edison's latest generator is simply outwardly a Siemens armature placed between the two checks of a powerful upright electro-magnet. It is not known yet what system of winding up of the wire he has adopted; though the armature possesses one peculiarity in having a number of strands of iron wire wound traversely between metal checks around the core, and the longitudinal coils of insulated conducting wire are wound on outside.

To this elegant investigation of M. Breguet there only remains one point to add, and it will form a fitting peg on which to hang our next and concluding article on the theory of the Gramme machine, namely, that the power of all these machines can be increased not only by increasing the number of turns of wire, and arranging them as advantageously as possible, but by increasing the intensity of the magnetic field in which they move by introducing iron cores into the very middle of the coils.

III.

In the two preceding articles we have explained the beautiful and simple illustrations devised by Monsieur Antoine Breguet in his researches upon dynamo-electric machines. The first of these dealt with general principles underlying all machines for generating electric currents by the rotation of conducting wires in a magnetic field. The second was devoted to the Siemens machine and the various possible systems, good and bad, of winding the wire upon the armature. We have now to approach by far the most important part of M. Breguet's work, and to explain his theory of the Gramme machine, the only theory which completely accounts for the action of the ring of iron in the armature. We shall in conclusion give some further considerations of extreme importance upon a fact known to all practical electrical engineers, but hitherto completely unexplained by theory, namely, that it is necessary to displace the commutator brushes of dynamo-electric machines from the position of symmetry, the angular displacement varying with the velocity of rotation, and with the work which is being done by the machine.

Suppose, firstly, that a wire bent in the form shown in Fig. 17 was placed upon the apparatus described in the preceding

articles and illustrated in Figs. 4 and 8, on pages 342 and 344. Under what conditions can it rotate? If a current passes through this wire, it will ascend branches 1 and 3 and descend branches 2 and 4. It is clear that there will be a tendency to move 2 in an opposite direction to 1; hence the forces tending to drive the conductor round will be two couples act ing in opposite senses, urging 1 and 4 in one direction, and 2 and 3 in tbe other direction round the axis. The couple 2

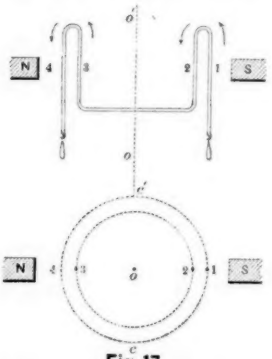


Fig. 17.

and 3 will be, however, the weaker of the two, since the length between 2 and 3 is less, and they are further removed from the most intense part of the magnetic field than are 1 and 4. The total force of rotation will clearly be the difference of the two opposing couples; and the arrangement, as it is, is evidently worse than the arrangement given in Fig. 4 of the first article. The rotation of conductors 1 and 4 is just *pro tanto* hindered by the opposing forces on 2 and 3. If only the action of the magnetic field on these two branches could be reduced to nothing, the effective force of rotation will obviously be increased. Now there is one way, and but one, to *screen off* the magnetic field from the branches 2 and 3, and that is by interposing a screen of iron in the form of a ring. To understand fully how the iron ring can act as a magnetic screen for the wires within it, it is needful to comprehend the nature of magnetic substances in general in respect of their behavior as screens.

We have, in the first article, spoken of magnetic lines of force as Faraday defined them, and their properties. The most important of these properties in the present regard is that they pass by preference through a magnetic substance, which, so to speak, conducts them better. Iron is about a million times as magnetic as air, hence we find that the lines of force in a magnetic field are very greatly altered in form by the presence of a mass of iron, as they have a tendency to so arrange themselves that they may run as far as possible through iron and as little as possible through the air or the surrounding space. For example, if Fig. 18 represents the magnetic "field" between two poles N and S, in which also a hollow cylinder of iron has been placed, it is found, by the method of sprinkling iron filings over a card laid in the field, that instead of assuming the usual simple arcs passing across from one pole to the other, the lines of force are bent about in a remarkable manner. They curve round so as to meet the ring, travel along in the substance of the iron as far as possible, then emerge at the other side to curve round sharply into the other pole. *The entire space within the ring is destitute of lines of force* and is thus screened off from magnetic influences.

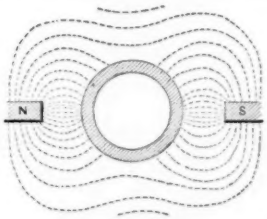


Fig. 18.

The interior of a hollow ball of iron is in like manner screened from all external magnetic influences; a property of which advantage was taken by Sir W. Thomson in the construction of certain galvanometers specially designed for use on board cable-laying ships. The cylinder of iron in Fig. 18 would serve equally well as a screen to the interior portions whether at rest or in rotation round its axis, for even if rotating the lines of force would prefer to pass through the iron rather than cross the interior air-filled space. The external field might be somewhat deformed in symmetry during the rotation, in consequence of iron requiring *time* to part with its magnetism, but this

would not affect the interior space where no magnetic forces are.

It will be convenient for our purpose to consider the effects produced in the magnetic field by a cylinder of iron so short that it may practically be considered a *ring*. This is shown in section in Fig. 19. Here we may notice several

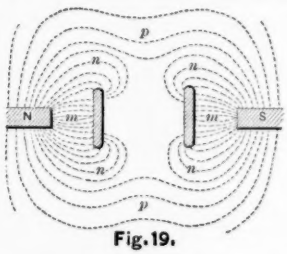


Fig. 19.

points. First the peculiar grouping of the lines of force. Most of them in the intensest parts of the field run straight from the pole to the ring, thence round through the iron of the ring invisibly, and emerge again at the opposite side. These groups of lines, marked *m*, indicate that the magnetic force is concentrated into that part of the field immediately opposite the poles. Nextly, there are certain groups *n* of less intensity which pass above or below the edges of the ring to curve round into it on the inner edge, and which in like manner run round the substance of the ring and emerge at the opposite side. Lastly, there are some outlying lines of force marked *p* which pass by above and below, and which are of no importance. It is particularly to be noticed that no lines

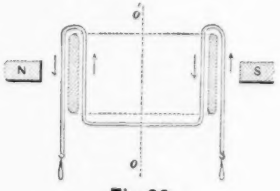


Fig. 20.

cross the interior of the ring to go from one pole to the other, so that the ring still acts as a screen.

Now suppose such a ring to be placed within the bent conductor of Fig. 17, the arrangement will assume the form shown in Fig. 20, where branches 1 and 4 of the conductors are exterior to the ring, 2 and 3 interior. Clearly, as far as 1 and 4 are concerned, they are more advantageously situated than before, for the iron ring intensifies the portion of the magnetic field in which they are situated. As to the branches 2 and 3, their condition is now wholly changed. They are chiefly screened from magnetic actions, the only lines that cross them being those of the groups *b*, but these lines instead of being merely lines of force, running across from N to S, are lines which actually curve round and cross them as if coming from S to N. Consequently the magnetic forces on 2 and 3 act in the reverse sense to what they did when there was no iron ring, and the force of rotation acting on 2 and 3 now tends to spin them round in the *same sense* as 1 and 4. The model illustrating this beautiful theoretical demonstration of the part played by the iron ring, was shown to the Société de Physique by M. Breguet at one of its meetings during

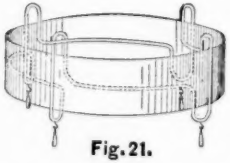


Fig. 21.

1879, and its performance was so perfect as to leave nothing to be desired. A further modification shown in Fig. 21, having four equidistant turns, is a still nearer approach to the Gramme ring. It only requires that a coil of many turns should be substituted for each single fold of wire, and that the number of such coils upon the iron ring should be increased, to obtain the true article. In that case, however, the commutator pieces would be made of small arc and proportionately numerous, as described in the preceding article. Up to this point we have treated the matter as if the Gramme armature were intended to rotate as in an electro-motor, converting an existing electric current into motion. The principle of *reversibility* laid down in our first article shows, however, that all the considerations advanced apply equally well to the case in which the motion of the armature in the field is employed to generate a current of electricity. As is

well known, the Gramme machine, besides being an admirable generator, is capable of being advantageously used as an electro-motor. It matters not, moreover, from a theoretical point of view, whether or not the iron ring is fixed, or rotates with the coils of wire upon it; though for practical reasons the latter is of course always the case.

We are now prepared to discuss the question whether the Gramme armature with its ring, or the Siemens armature with its longitudinally wound coils, is the more advantageous. It will be admitted that the only effective portions of the coils of the Siemens armature are the wires parallel to the axis of rotation, and that those portions which cross the ends radially are comparatively useless, as they cut few lines of force, and add to the total resistance. Also, in the Gramme armature the effective portions of the coils are those external to the ring, the wires along the screened internal face cutting few lines of force. Hence, given two rival machines having equally intense magnetic fields, equal velocities of rotation, and therefore equal electro-motive forces, that machine will have the advantage in which the shortest wire can be coiled into the greatest number of effective turns. It must be remembered that one turn of the Siemens armature corresponds to two turns on the Gramme armature taken at opposite points on one diameter of the ring. Hence, the calling the longitudinal dimension of either armature l, and its diameter d, the length of wire necessary to make one complete turn of the Siemens armature will be $2\ (l+d)$, while that necessary to make the equivalent two turns of the Gramme ring will be $4\ l$ (neglecting the thickness of the iron ring, which may be relatively small). Hence, the Gramme will be better if $4\ l$ is less than $2\ (l+d)$; the Siemens better if $4\ l$ is greater. If $4\ l=2\ (l+d)$, or if $l=d$, then they will be of equal power. Hence, it follows that of necessity the Siemens armature should be long in proportion to its diametral thickness, while the Gramme will be best if the diameter of the ring be greater than its thickness parallel to the axis. For reasons of construction it is also found advisable to make the rings of the Gramme machine flat wide rings rather than deep narrow ones.

We will now finally follow M. Breguet into his inquiry into the cause of the dissymmetrical position of the commutator brushes of dynamo-electric machines. Experience has dictated that to obtain the best possible results it is necessary to adjust the brushes which take the current from the commutator to an oblique position, different from that dictated by theory. Moreover, the amount of this angular displacement is found to vary with different speeds of the machine, and with the work done in the circuit. Neglect of this matter leads to sparking at the commutators and consequent wear and waste. In the Brush machine and in the Weston, and some other forms, there is indeed a particular adjustment to enable the brushes to be set at will. Another point which has hitherto been quite unexplained is that if the machine were being employed as a generator of currents, this displacement of the brushes

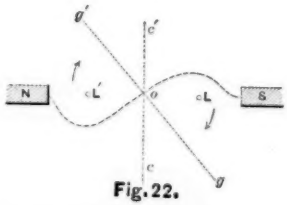


Fig. 22.

must be a lead, or a displacement in the direction of the rotation, while in the case in which the machine was used as a motor, the brushes must be displaced in the opposite direction to that of the rotation, or with a negative lead. In spite of these plainly incompatible conditions it has always been customary to attribute the practice thus dictated empirically by experience to the slowness with which the soft iron of the armatures loses its magnetism, or in other words to the retardation of demagnetization. If we go back to the simplest of all the forms of movable rotating conductor we have considered, it will be apparent that the best moment for changing the direction of the current in the conductor is that instant when perpendicular common to the conductor and to the effective lines of force in the field passes through the axis of rotation. Thus in Fig. 22, if the lines of force ran straight across the field from pole N to pole S, then clearly the best

points to reverse the current would be at *c* and *cl*, or on a diameter at right angles to NS. Now, up to this point it has been *assumed* that the magnetic field is symmetrical across between the poles, and that the greatest number of effective lines of force run across straight from N to S, or at least in gentle arcs symmetrically above and below the line N S. As a matter of fact this is never the case, since the presence of the conductors carrying the vertical currents is sufficient to introduce serious modifications in the positions of the lines of force. Around the conductors which carry the electric currents there is also a "field" of magnetic force in which the lines of force are arranged, not radially as about the poles of magnets but in concentric circles. The presence of the current then changes the total directions of the forces at work in the field, and throws the lines of force into new places. In fact, as mentioned in our first article, the principal lines running across the field from N to S will be distorted, as shown in Fig. 22 into an S-shape, illustrating unmistakably the tendency to move in opposite directions the conductors L′ and L, in which the current is flowing in opposite ways. From the principle laid down above, it follows that the most advantageous position to reverse the current is, therefore, not along the diameter *c c′*, but along the diameter *g g′*, drawn at right angles to the chief line of force at the center. The angle between these two diameters is clearly the angle at which the contact brushes ought to be displaced, in order that the current may be reversed at the most favorable moment. We are here considering the case where a current is being used to produce motion, that is to say, where the Gramme machine is being used *as a motor*. Now the form of the S-shaped line will depend on the relative strengths of that part of magnetism in the field due to the field magnets N S, and that due to the current. If the current is relatively weaker, the S-shaped curve will be more nearly a straight line, if the current be powerful (relatively to the magnets) then the line running from N to S will be a well-formed S. Now, this clearly implies that if the current is strong, relatively to the magnet, the angular displacement of the contact brushes, *c′ o g′*, will be great, while, if the current is relatively weak, the displacement of the brushes will be small. Again, it is well known that when an electro-motor is running with a great velocity there is a reaction current set up in it in an opposite direction to that which produces the motion and tending to produce an opposing electro-motive force. If an electro-motor is allowed to run very rapidly this opposing induced current will reduce the supplied current to a fraction of its original strength. The maximum work is done by an electro-motor when this reaction current just halves the original current. Hence, if an electro-motor whose armature is running in an invariable magnetic field be doing light work, and therefore be running very quickly, the reaction current will reduce the total current in the conductors relatively to the power of the magnets, and under such circumstances, the displacement of the contact brushes will be small. If the motor be doing heavy work, and its velocity be therefore slow, the reaction current will be feeble and the total current strong in proportion to the magnets, hence the brushes must be displaced through a large angle. The rule, therefore, for dynamo-electric machines used as *motors* is that the contact brushes must be displaced in an inverse sense to that of the rotation of the armature, and with an angular displacement, which is greater as its velocity is less, or as the work done by the motor is greater.

Now consider the case where the machine is used as a generator. If the armature be driven round in the field mechanically, the current generated will be in the opposite direction to that of a current which we have supposed to produce a rotation in the same sense. Hence, if we think of the magnetic forces due to the current thus induced in the conductors we shall see that they will produce a displacement of the lines of force in the field, but this displacement will be the converse of the former case; the chief line of force crossing the center of the field will be S-shaped as before, but will be reversed in position as compared with that shown in Fig. 22, and will pass from N above L′ below L, and so to S. In this case the diameter of commutation *g′ g* will cross the line *c′ c* from right to left, and the contact brushes must be dis-

placed in the same sense, as the rotation of the armature, or must be set so as to have a true lead. Here again the question of the relative strength of the magnetic forces due to the current and to the magnets comes into play. If the field magnets be simply permanent steel magnets, or if they are electro-magnets excited by a current generated independently from another source, then the electromotive force in the rotating armature will be, as shown by the researches of Mascart and Angot, and others, simply proportional to the velocity of rotation. In that case, if the resistance of the circuit is constant, the strength of the current will also rise proportionally to the velocity and the deformations of the field, and hence the angular displacement of the contact brushes must be greater as the velocity is greater. The rule is, therefore, for magneto-electric machines, and for those dynamo-electric machines in which the field magnets are separately excited, when used as generators, that the contact brushes must be displaced in the same sense as that of the rotation, and with an angular displacement which is greater as the velocity is greater.

Finally, take the more common case where the field magnets of the dynamo-electric generator are excited by the current generated, or are included in the circuit of the machine. With small velocities before the electro-magnets have nearly attained their maximum magnetization, the strength of the magnets will increase as the strength of the current. Hence the relative intensities of magnets and of current grow almost at the same rate, and the displacement of the contact brushes need only be small. With greater velocities, however, and stronger currents, the magnets will begin to approach their condition of saturation, when any increase in the strength of the current no longer produces anything like a corresponding increase in the power of the magnets. Under such circumstances it is clear the deformation of the lines of the field will become greatly exaggerated, and the displacement of the contact brushes must be very great. M. Breguet tells us that with magnets too small in proportion to the armature, and with a velocity of 1770 revolutions per minute, he has succeeded in obtaining conditions which necessitated that the contact brushes should have a lead of 70°. A simple calculation leads to the conclusion that for great velocities the tangent of the angle of the lead should be proportional to the number of revolutions per minute.

Before entirely quitting the subject, we will just state what part is really played in this phenomenon of dissymmetry of commutation by the tardiness of the iron ring in receiving or parting with its magnetism. The presence of the iron ring exercises two influences quite distinct from one another. Firstly, since it requires time to magnetize or demagnetize it, it will necessitate that the contact brushes be displaced a little in advance of their theoretical position, or with an increased lead. This displacement, always in the sense of the rotation, will, therefore, diminish the total displacement where the machine is used as a motor, but will increase it where used as a generator. In either case, however, its influence is quite small. M. Breguet found experimentally that even with the enormous speed of 1770 revolutions per minute the displacement due to this source did not exceed 10°. Secondly, the presence of the iron ring increases the intensity of the magnetic field, concentrating a greater number of lines of force in it, and, therefore, tending to reduce the deformation in its symmetry. This is a most important influence, and it will be seen that in the case where the machine is used as a generator the presence of iron in the armature tends to bring back the most favorable position of the contact brushes towards the position of symmetry, that is, tends to *diminish* the angular displacement which must otherwise be observed. The action of the iron of the ring is, therefore, absolutely the contrary to that commonly attributed to it; for, so far from necessitating a displacement of the contact brushes in the direction of the rotation, it absolutely serves to diminish, and that very considerably, the angular displacement necessitated by the dissymmetry of the magnetic field.

The researches of M. Breguet place the whole theory of the Gramme machine in a new and intelligible light. They not only clear up the discrepancies hitherto existing, but lay down the basis upon which all future dynamo-electric machines

must be constructed. The part played by the iron ring as a magnetic screen comes now for the first time to light; and by the aid of the reasonings now put forward one begins to see the *rationale* of many details hitherto dictated only by empirical practice. It is to be hoped that practical electricians will not be slow in turning these careful and ingenious deductions to good account.

THE SEWAGE OF LONDON.

From "Nature."

General Scott, in his recent paper at the Society of Arts, entitled "Suggestions for Dealing with the Sewage of London," deserves credit for having drawn attention to a subject which in itself must have especial interest for all residents in the metropolis, but which, from the manner in which he has dealt with it, possesses further attractions for those who have made the scientific aspects of the sewage question their study, in that he has really attacked this much-debated problem in an entirely new direction, and has in so far entered upon fresh ground. We do not remember that any previous investigator has set himself the task of examinining into the composition and character of the suspended matters of water-carried sewage, coupled with the possibility of the mechanical separation by simple subsidence (1) of the heavier mineral particles of the detritus, and (2) of the lighter flocculent particles; which latter, consisting as they do mainly of the fecal matters, possess a far higher manurial value than the heavier substances washed from the roads and pavements.

The sludge deposited from sewage by one or the other systems of precipitation has received hitherto the chief share of attention from scientific men, and even when the possibility of recovering the solid matters in sewage by some system of straining or rude filtration, or the retention of such solids in tanks in which the sewage is brought to temporary quiescence, has been considered, it seems on all occasions to have been the practice to regard the entire bulk of such deposits as an inseparable compound of very low value from the manure point of view. It is, of course, the manurial value of the ingredients contained in suspension and in solution in sewage which has been so frequently inquired into by chemists; and, beginning with the report of Dr. Hoffman and Mr. Witt in 1857, down to that of Messrs. Rawlinson and Read in 1876, a vast mass of valuable information concerning the nature, composition and value of the manurial elements of town sewage has been accumulated. It has remained for General Scott to point out that—

1. A very large proportion of the solid suspended matters may be removed from sewage by simple subsidence.

2. That such matters may roughly be separated, the more valuable from the valueless, by the method in which such subsidence is accomplished.

3. That after such preliminary treatment, any chemical process for the clarification and partial precipitation of the dissolved impurities of sewage may be carried out far more readily, and under conditions rendering their success in an economical point of view one of greatly increased probability.

4. General Scott has indicated various simple methods for dealing with the silt and detritus removed from the sewage at a relatively small expense; of deodorizing and fitting the sludge obtained by subsidence for the manufacture of a manure; and lastly, a mode of further purifying the London sewage by a system of chemical treatment whereby it may be rendered suitable for discharge into a river of large volume.

Assuming the dissolved impurities to be incapable of recovery unless the sewage water can be utilized for irrigation, the first object of General Scott's paper was to show how large an amount of harm was done to rivers and the dwellers on their banks solely by the solid matters contained in sewage. By means of extracts from the reports of the various Royal Commissions who have examined into this question, and the information furnished to the Metropolitan Board of Works by their own advisers, Messrs.

Bidder, Hawksley and Bazalgette, he proved that the deposits in the river, the mud banks, the foul emanations from which were most unhealthy, and the dangers to navigation, were all due to the discharge of the solid ingredients of raw sewage into rivers and into the Thames.

General Scott next entered very minutely into the composition of the suspended matters of sewage. An estimate of the total weight of solid matters due to a mixed population of 3,500,000 persons, with a proportionate allowance for the fertilizers existing in the excreta of animals, together with the *débris* of the animal and vegetable substances which might find their way into the sewers, would manifestly represent the sum total of the organic matters in London sewage.

Concerning the gross annual amount of organic matters, different estimates appear to vary very slightly, and in assuming them in the case of London at 50,000 tons per annum, there would seem to be but a small margin for error; the quantities of detritus, however, have been very differently stated by the various authorities. From the most reliable analyses of the London sewage, taken at all periods of the day and night, and in many different parts of the metropolis, there appears to be a tolerable unanimity in assigning the ratio of the organic to the mineral ingredient of the suspended matters to be as 1 is to 2. After a period of settlement, it is found that the proportion is, by the subsidence of the heavier mineral particles, exactly reversed, as the larger portion of these valueless components of sewage impurities rapidly subside, entangling with them about one-fifth of the organic matters in suspension. General Scott proposes, therefore, a double system of tanks. The first set would consist of a series of shallow catch-pits, in which the sewage will only be brought to a state of partial repose, and in which it will part with about four-fifths of the solid mineral matters and one-fifth of the organic matter. In the second set of tanks, in which more time will be given for the settlement of the matters in suspension, the sewage will be deprived of nearly all the remaining suspended impurities, namely, one-fifth of the mineral and four-fifths of the organic matters. If we assume the gross weight of the organic matters at 50,000 tons per annum, the mineral ingredients will, according to the analyses quoted by General Scott, equal 100,000 tons, and the total of 150,000 tons thus obtained is, in reality, a very low estimate of the amount of the suspended matters in London sewage. These matters, General Scott is of opinion, he could roughly separate in his tanks thus: In the detritus tanks he would obtain 80,000 tons of mineral matters, together with 10,000 tons of organic matters; in the second set of tanks he would expect to find about 20,000 tons of mineral matters mixed with about 40,000 tons of organic matters. The exact percentage composition of this latter sludge would, he believes, after studying and comparing many analyses and valuations, be somewhat as follows:

Organic matter (without nitrogene).....	66.50
Nitrogene.....	3.50
Phosphoric acid 2.80 = tribasic calcic phosphate.....	6.07
Potash.....	1.25
Sand and inert mineral matter.....	22.68
	100.00

In the debate which took place after the paper, Dr. Frankland, while admitting General Scott's process "worthy of trial," took exception to this estimate, and maintained that his experience was "that after the separation of detritus from London sewage, the maximum percentage of organic matter was 63, whilst the minimum was 21, the average being 39½, and these high percentages were obtained under exceptionally favorable circumstances, because, in the collection of these samples of sewage, little or none of the so-called detritus was mixed with it at all." He further stated that "he did not think it would be safe to calculate on more than 33 per cent. of organic matter in the dry sludge." This question of the possibility or otherwise of effecting a separation more or less perfect, of the mineral from the organic elements of the sludge lies at the root of General Scott's proposals, and while giving all due weight to Dr. Frankland's high authority, we are compelled to admit that General Scott's figures, many of them based on the analyses of Dr. Frankland himself, seem to point in the opposite direction to that pointed out by Dr. Frankland, as con-

cerns the relative proportion of the mineral and the organic matters after settlement.

The question to be decided is, admitting the composition of the sewage solid to be in the first instance 2 mineral to 1 organic, can we reduce this proportion to 2 organic to 1 mineral, by bringing the sewage to a state of quiescence in tanks? This could be tried on a sufficiently large scale to settle the point at issue in a very short time, and it is a question which to a great extent depends upon the result of actual experiment on a large scale, it is certainly one for the officers of the Metropolitan Board of Works to decide.

Passing over the theoretical values of the deposits based upon their contents in nitrogen, phosphoric acid and potash, which General Scott has dealt with very carefully, we come to the question of deodorizing the sludge and its preparation as a manure. For the former purpose the employment of slaked lime is advocated, used in the small quantity of only .66, or less than 1 per cent. of the total weight of the sludge. This slaked lime, made into milk of lime by the addition of water, is to be thoroughly incorporated with the sewage deposit, and a sufficient amount of crude superphosphate is then to be added, in order nearly, but not quite, to neutralize the lime. A crystalline precipitate of phosphate of lime is thus formed in the sludge, which greatly aids in the drying of the compound, or, to put it more correctly, facilitates the extraction of the water. Some of those who took part in the debate doubted whether General Scott, in his estimate of 20s. per ton on the dried material, which included the cost of chemical treatment, had made a sufficient allowance for the great labor and difficulty which would have to be incurred in drying the sludge for use as a manure. Dr. Voelcker, who pointed out that "he had gone very carefully into the figures in the paper, and was very glad to find that General Scott had avoided those exaggerations which frequently disfigured calculations of this kind," quoted some observations he had made tending to show that sewage sludge parted with water with extreme difficulty, though he admitted that after treatment with lime and phosphoric acid such sludge would dry with greater rapidity. In the various forms of filter presses now largely used for drying clay slip and expressing precipitates, very great improvements have recently been effected, and it has been stated on good authority that it becomes possible by their use to reduce the moisture in such materials as low as 50 per cent. There still remains, however, a large proportion of water to expel, and, as Dr. Voelcker stated, this can only be accomplished by means of artificial heat.

The question of the cost of drying sludge is one which possesses many features of interest, and the entire subject would be one well worthy of the special consideration of the Society of Arts at their annual conference on the treatment of sewage. We should like to have devoted more time to the calculations of General Scott of the theoretical value of the three chief fertilizers present in sludge, viz., nitrogene, phosphoric acid and potash, as also to the expense of preparing soluble phosphoric acid, concerning which latter point Dr. Voelcker threw out some valuable suggestions during the discussion, but we must now conclude. We entirely agree with General Scott in his denunciation of the folly and imprudence of continuing to cast raw sewage into the Thames; he has certainly pointed out a way of greatly abating the present evil, and as the plan he advocates could be tried upon a sufficient scale at an almost nominal expense, we feel justified in urging with Dr. Frankland that this should be done, and we cordially echo his concluding observation "that the Board of Works have no right to look for a profit in getting rid of the objectionable matter. If they can succeed in doing it without a loss or at a cost not greater than that involved in dredging it out of the river again, it ought to be done; because if sewage mud is deposited in the river there must be an obstruction to navigation, besides the putrefaction of organic matters which, when deposited on the banks of a tidal estuary, become very offensive, especially in warm weather."

So far as one can judge from the facts adduced by General Scott, his scheme promises to be more efficient for the ends aimed at than any hitherto proposed, and certainly it seems to us that the great scientific principles which are applicable to the subject have been kept

well in view. And from our standpoint this must be the test of the efficiency of any scheme for the disposal of sewage. We fear that hitherto those with whom the decision rests as to what scheme shall be adopted for the disposal of the sewage of London have looked upon the question too much as one between rival "schemes," and considered far too much the supposed interests of rival "bodies," and too little the clear teachings of science and the welfare of the public. It is evident that for London, at least, the whole subject of the disposal of sewage will have very soon to be reconsidered, and we trust that the authorities concerned will take into their council reputable chemists and physicists, who, we are sure, can have no interests more at heart than to see the unmistakeable teachings of science practically applied to the salvation of society.

CARBON, CRYSTALS AND SILICON.

By the Rev. J. C. BROWN, LL. D.

From the "Journal of Forestry.

THE success of Mr. James Mactear and of Mr. Robert S. Baxter in procuring crystals from carbon—the report of Mr. Maskelyne that some of those submitted to him for examination were not crystallized carbon, but some crystallized silicates—and the statement of Mr. Mactear that some of them consist entirely of silica and alumina with a little magnesia, recall a like discovery, with like results, which excited like interest some forty years ago, some people rejoicing in the light likely to be thus thrown upon the atomic condition of so-called elements, and others ridiculing the alleged discovery, and the supposition that it would lead to further discoveries in the direction indicated. About that time Dr. Samuel Brown obtained, in the course of experiments in which he was engaged, some beautiful crystals which were considered by him, and associates in his work, crystallized carbon, such as the diamond; and great was the joy which was thus produced. What Mr. Maskelyne describes in his report as "the problem of the permutation of carbon from its ordinary opaque black condition into that in which it occurs in nature as the limpid crystal of the diamond," seemed to have been solved, and solved by him.

Subsequent examination and experiment satisfied him, however, that these crystals were not artificial diamonds, but, to use again the words of Mr. Maskelyne "some crystallized silicate," as it seemed to him pure silicon, or crystals of quartz; and the full significance of this was realized by him at once. If these were silicates, and no silex had found its way into the material whence they were produced, then silex had been formed of carbon,—one of the substances considered as a simple element had been formed of another substance considered as a different simple element: a veritable transmutation of one *quasi*-element into another had occurred.

Let it be noted, however, that there is an important assumption here—an assumption the full importance of which perhaps none but a chemist can fully realize—the assumption embodied in the statement *if no silex had found its way into the material from which the crystals were produced.* On this point he had no doubt; but he labored—labored long and labored hard—to devise other processes, which should satisfy others that all access of silicate had been effectually prevented. And whenever a possible source of error was discovered by himself, or by friend or foe, he set himself at once to devise yet another process by which proof could be given that not thus had the crystals been produced.

Partly with a view to protect his discovery, partly with a view to testing it, and partly in prosecution of the course of discovery upon which he had entered, he applied his method of investigation to others of the so-called elements, and with like success.

His procedure was not empirical,

but was based on views admitting of explicit statement, and was carried out on principles well defined.

His general views of the atomic constitution of matter, similar to those of Boscovich, are given in a posthumous work entitled "Lectures on the Atomic Theory, and Essays Scientific and Literary."

These lectures, delivered before a select audience in Edinburgh in 1843, excited much interest amongst thinking men by whom they were attended. Dr. Chalmers, Lord Jeffrey, and Sir William Hamilton were, I believe, amongst those of them who afterwards publicly expressed their interest in the views advanced.

His working hypothesis was that the so-called elements are each of them composed of atoms of elements of more simple composition. The atomic theory of Boscovich admits of a conception of such an hypothesis being grafted upon it; and the isomerism of cyanogen and paracyanogen, of oxygen and ozone, may be referred to in illustration of what is meant.

The view taken of the atomic constitution of any of the so-called elements precluded any hope of being able by analysis to reduce a more complex one to its constituents, but left open to experiment the application of any device for synthetically producing the more complex out of the more simple. This he sought to effect by bringing atoms of the more simple, in a nascent condition, within the sphere of each other's chemical attraction; and this he effected with more than one of the metals. Of this fact he made no secret; but he deemed it inexpedient to widen a controversy which was produced by the publication of his first discovery, which was that to which I have referred.

It appears to have been in the beginning of 1834, while attending Dr. Hope's lectures on chemistry in the University of Edinburgh, that he first caught the idea of the possibility of producing the diamond from amorphous charcoal. In the course of experiments thus suggested he succeeded in producing a beautiful crystal in 1836, while engaged in endeavoring to solve laws regulating the process of crystallization. Information of this was communicated to two of his fellow-students with whom he was working, and to Dr. Christison, in whose laboratory they were at work; and there opened upon him a far-reaching vista of research. It seemed to be a diamond; but that was not all; and, as has been stated, subsequent research satisfied him that similar crystals which he obtained were not diamonds, as many of his fellow-students, who had heard vague accounts of what he had accomplished, boastingly alleged. Under the date of 19th October, 1838, he wrote to his sister, "These crystals must have been siliciurets produced by the transmutation of carbon into silicon." And the results of his experiments he embodied in a paper which he read to the Hunterian Society early in the session. He graduated as Doctor in Medicine the following year; and his thesis was entitled "Chemical Fragments, and Carburets and their Crystallization, &c.;" and for this he was awarded one of the gold medals given by The Faculty.

In both of these he gave explicit statements of his views as held at that time. They may be crude, as I have heard them characterized, and, as I am told, he himself afterwards considered them; but they are not without interest as indicative of the progress of research; and the experiments detailed may be found not without value, as suggestive of what may be done, or as supplying data of negative, if not of positive importance.

He was suffering from incipient disease, and he was feeling depressed by grief, and to some extent distracted by business, consequent on the death of his father, and of a beloved friend, while he prosecuted his subsequent researches; but he ceased not till satisfied beyond all doubt of the reality of his discovery. Writing of this to a friend, he said, "I doubted, and feared, and trembled at my discovery, till a fiftieth uncorruptible witness gave me assurance that nature had not indeed deceived me on that eventful night."

To another he wrote under the same date, 27th June, 1840, "During the last six weeks I have changed given weights of cyanogen, carbon, tin, lead, and silver into the same weight of paracyanogen, silicon, lead, mercury, and gold;" and by the close of the year he had arranged

several of the so-called elements in isomeric groups.

His first public announcement of such results obtained by him was a paper, "On the Preparation of Paracyanogen in large quantities, and on the Isomerism of Cyanogen and Paracyanogen," which was communicated to the Royal Society of Edinburgh by his friend and teacher, Sir Robert Christison, on the 15th of February following; and it was subsequently published in the fifteenth volume of the Transactions of the Society, which step was resolved on under a realizing view of what was implied in the measure, to which expression was given by Principal Forbes in the statement, "The interests of the Society are now at stake." The selection of the subject was made—not on the ground of its relative importance, but in view of the controversy which he foresaw must ensue on the publication of his discoveries, and the facilities which this supplied for easily and thoroughly testing the principles involved.

In this paper are detailed various processes, the design of which as stated by him was "to decompose the bicyanuret of mercury at such a temperature, and under such a degree of pressure as to secure the simultaneous extrication of the two equivalents of cyanogen or their elements, in the expectation that they should come off united, and produce the interesting compound of nitrogen and carbon isomeric with cyanogen and paracyanogen, and that result was sought in the belief that it would illustrate the chemical theorem of the existence of bodies, which, though composed of the same elements in the same proportion, yet differ as widely from each other in chemical properties and mechanical conditions as one element differs from another."

The memoir was designed to be introductory to a second, in which the same method should be applied to substances recognized as essentially different, and considered as elementary, simple, undecomposed bodies, incapable of decomposition. This second, bearing the title "Researches on the Production of Silicon from Paracyanogen, with Details of Experiments and their Results," was read before the society on May 3, and with it was lodged a sealed paper containing information in regard to other processes whereby the transmutation of the so-called elements had been effected. After his death this packet was returned by the Society to his widow.

The statements in this memoir gave occasion for much comment and remark; and circumstances arose which gave occasion for greater keenness in some of those which subsequently were made. By some it was felt to be a subject which must be decided by experiment and not by disputation; and under this feeling Dr. George Wilson came forward and offered to repeat the experiments detailed, in company with Mr. J. C. Brown, Jr., a cousin of Dr. Brown, who was familiar with the method of experiment followed, and to report the results. They did so; and their report was submitted to the Royal Society, and published in their Transactions in, I think, the year 1844.

It appears that they considered the most satisfactory results would be obtained by quantitative analysis, and to this they gave their chief attention, but they failed to obtain satisfactory results. When they obtained the same material results obtained by Dr. Brown it was not in anything like the quantity in which he had done; nor did they always obtain this; nor could they tell why in some cases they succeeded and in others they failed.

The title of the paper is "An Account of a Repetition of Dr. Samuel Brown's Processes for the Conversion of Carbon into Silicon, by Dr. George Wilson and Mr. Croumbie Brown." It appears that:

1. They obtained silicon from bodies not containing that element, every precaution against the insinuation of silicon from any external source having been taken.

2. They never procured the whole weight of carbon employed in the shape of silicon.

3. They got sometimes more, sometimes less silicon, they could not tell why.

And it was argued by others—1st, the silicon must have been formed either from the carbon; or 2nd, from nitrogen existing in the materials employed; or, 3rd, from both: and in any case the appearance or formation of another of the so-called elements was put beyond dispute. With many experiments made

by Dr. Brown there had been like varying results obtained. It was the one fact that silicon had been found which was essential. He considered he had reported processes which could not fail in competent hands. The fact that they had failed in the hands of Dr. Wilson and Mr. Brown showed that they came short of what he had supposed, and that his details had been deficient in explicitness; and he quickly set himself to devise, if possible, a crucial experiment which could not fail in the hand of a competent chemist, and in which the presence of silicon in the product obtained could not possibly be accounted for, on the supposition that it had been produced otherwise than from carbon employed. But he died before such a crucial experiment could be discovered.

His life was prolonged for years. Many of them were years of suffering.

Processes were devised which made those which he had published appear crude—correct, but crude; and in the year 1853, during a period of bodily depression, he gave expression to a passing thought that the crystals he had obtained from carbon might not be siliciurets after all; but never, excepting on that occasion, do I know of a doubt on the subject having been entertained by him.

The difficulty was not to devise other processes than those he had published by which like results might be obtained, but a crucial experiment—a process by which the fact could be established beyond all doubt or cavil. At length, on his death-bed, with quickened intellect he saw—or thought he saw—how this might be effected. And some little time before his death he said to the writer, "Could I but have three days of strength to rise and resume my work, it would be done." But his strength was gone.

In this stage the subject has remained ever since. It is stated that transmutation of one metal into another has occurred accidentally in America—that the same, or a like transmutation of one metal into another, has been effected in Europe—and that both in vegetation and in animal life phenomena have been observed which are in accordance with a supposition of a transmutation of *quasi* elements having been effected. And now the observations of Messrs. Mactear, Baxter, and Maskelyne prepare the way for reopening the question of forty years ago relative to the production of silicon from carbon.

THE WATER WORKS OF TOKIO, JAPAN.

By W. S. CHAPLIN.

Written for VAN NOSTRAND'S MAGAZINE.

THREE rivers enter the bay of Yeddo at its northwest corner, the Sumida, the Naka, and the Yeddo, the first being on the west. The land near and between their mouths and along the bay is but little higher than the water of the bay, and is probably of a very recent formation. Indeed maps made only two hundred years ago show that much of the district now occupied by the city of Tokio was then covered by the water. Geologists say that the whole region near the head of the bay is being raised at a rate of about one foot in a century, and, as the land is almost level, it seems probable that not very long ago this whole plain was under water.

West of the Sumida, now, the low plain abruptly terminates and a line of hills begins, which ends in a gently rolling plain that reaches back to the mountains, a distance of from twenty to thirty miles.

The city of Tokio covers the low land on both sides of the mouth of the Sumida and along the bay, and reaches back over the hills on to the higher plain beyond. It may easily be divided into two parts; the low part in which the surface is seldom more than ten feet above the mean level of the water in the bay, and in many places not more than five feet above it; and the high part, from forty to one hundred and twenty feet above the same level.

The low part is by far the more densely settled of the two. It is the business portion of the city. It is intersected by numerous canals, which afford easy communication with all the

principal districts. The streets are narrow, from twelve to twenty feet wide, except the main street which is somewhat wider. There are as a rule no sidewalks, and drainage is provided for by narrow, shallow, open drains placed close to the houses on each side.

The higher part is occupied principally by dwellings, although the more important streets are lined by rows of shops.

The houses are as a rule one story high and built of wood in an extremely light style; but in the business quarter and along the main streets, there are many buildings two stories high and built in the way in which the Japanese build fireproof buildings. It may be interesting to describe these structures —called godowns by foreigners, kura by Japanese:

A foundation is made by either driving piles about six feet long, or by ramming large stones into the ground where the walls are to be. On this foundation a stone wall a foot or two high is built; and on this wall a heavy framework of wood is raised. The interstices of the framework are filled in with interlaced bamboo, and the whole is then covered with a layer of tenacious mud which has been dredged from the bottom of the canals or river. When this mud is dry another layer of mud is put on, the various layers being held together by strings which are fastened to the bamboos. After several coatings have been put on and the whole is thoroughly dry, a finishing layer of thin mortar is put on. Generally the mortar is colored black, and, while it is hardening it is rubbed and polished so that the whole building is of a shiny jet black. The windows and doors are frameworks of wood covered with mud. Great care is taken to make the building air-tight. When in good repair, these buildings appear to be proof against Japanese fires, but it does not seem probable that they would resist the greater heat caused by the burning of the heavy buildings of foreign cities.

The water obtained from wells throughout the city is bad; near the bay it is brackish, while further inland it contains such impurities as to make it unfit for drinking purposes. In the high portion of the city the wells have to be made from forty to sixty feet deep, and even at that depth they afford but a limited supply.

The area of the city is 16.1 square miles, and it has 799,975 inhabitants and 219,307 buildings.

The city is provided with a system of water works which when it was built was as good as that of London, and much better than that of Paris. The facts which can now be obtained concerning the building of these waterworks are very meager, as the records are said to have been burned in a great fire which destroyed nearly all the city a few years after the works were completed. Yet as the Japanese methods of doing work are probably about the same now as they were then, we may easily replace what has been lost.

About ten miles back of the city, to the west, are three small lakes from which a canal was made to the city early in the seventeenth century. This canal, called the Kanda canal, could not have furnished a great amount of water, as the lakes are small and shallow and drain out an inconsiderable tract of land. Now they are filled with water plants, and look as if the water which comes from them must be very impure. The people living near them say they are supplied by springs, which is probably a fact as the water which comes from them in summer is quite cold.

It appears that the Kanda canal did not supply the quantity of water needed, as in 1653 another canal was made to bring to the city the water of the Tama river, which empties into Yeddo bay about eight miles south of Tokio.

This Tama canal begins at a point where the Tama river leaves the mountains and enters the plain. The works for turning the water into the canal are very simple, but seem to be sufficient. The river here when it is full is about six hundred feet wide and ten feet deep; but when the water is low the stream only occupies about one hundred feet on the northern side of the bed. When the water is high no dam is required; but when it is low, a temporary dam is made by placing heavy timber stringers at the surface of the water from the shore out to a crib-work pier, which is built in the stream, and then from this one along to two others. Upright pieces

are placed about two feet apart on the up-stream side of the stringers, and against the uprights straw matting is placed. A few shovelfulls of earth thrown on the bottom of the matting make the dam tight. When the water rises and the dam is consequently not needed, the uprights and matting are carried down stream, and the stringers, which are fastened to the piers at one end, swing around so that the whole channel is open for the water. Labor is so cheap that it is doubtless more economical to replace the dam when necessary than it would be to build a permanent dam.

The line of the canal is so chosen that nearly its whole length it is in excavation; and this was not at all difficult as the plane is nearly level. In one place the water filled a shallow depression in the ground. It is said that it was then thought by the Japanese that the cherry tree absorbed poison from water; for this reason the banks of this small lake were lined with a row of cherry trees, which are still standing.

The banks of the canal are not protected in any way. The material of which it is made hardens under the influence of water, so that the banks are now nearly vertical and but very little worn by the water.

There are several branches from the canal which carry water for irrigation to many villages situated to the north of the canal, and other branches running southward back to the Tama, afford power to drive mills for cleaning rice and grinding flower. So much of the water is drawn off by these branches that only about one-fourth of what leaves the Tama reaches Tokio. A rough gauging near the head of the canal showed that 150,000,000 gallons daily entered the canal in the dry season of the year, and it is probable that only about 40,000,000 gallons go into the pipes of the city.

Near Tokio the two canals—the Tama and the Kanda—are connected, so that about one-half the supply of the Tama canal goes into the Kanda pipes.

Where the Tama canal enters the city there is a long masonry chamber, in which there are gratings for stopping floating bodies, and gates for shutting off the water. The Kanda canal formerly was open for some distance into the city, and as it is run through the middle of a street of course the water was much contaminated by surface drainage. This portion of the canal has, however, been lately covered with an arch. These two instances and a bridge by which the water is carried over the Kanda river are all the difficult works in the whole system.

The mains and pipes through the city were formerly made of wood; recently, however, stone conduits have been built in some streets, and a small quantity of iron pipe laid down, but wooden pipes are still mostly used in repairing and extending the system.

The small wooden pipes, say up to eight inches square inside, are made by cutting out a square timber so that it forms three sides of a box, and nailing on a plank for the fourth side.

The mains, which are sometimes two and a half feet square, are made of planks, which are fastened together by driving long spikes obliquely through the edge of one plank into the next. The joints are caulked with a fibrous bark. The pipes seem, when new, to be very tight. On the average these pipes last seven or eight years, but in some cases they have gone without repairs for more than one hundred years. In any other country the expense of making and replacing pipes would be enormous, but here, although the timber is all sawed by hand, and the smaller pipes are cut out with adzes, labor is so cheap that up to the present this system has been considered less expensive than it would be to use pipes and mains of iron.

When several pipes meet, or when it is desirable to reduce the size of the pipe, a large box is put into the ground, into the sides of which the pipes are introduced. These boxes generally reach above the surface of the ground, in a few cases as much as ten feet, and the tops are closed with heavy covers. Perhaps these boxes serve as depositing basins.

The water is not carried into the houses, as is the custom in other countries, but is delivered into what, for lack of a better name, we may call wells. These wells are made in exactly the same manner as the ordinary wells are, except that in some cases the bottom is closed. A hole three or four feet in diameter is exca-

vated and lined with hooped wooden cylinders, somewhat as if a number of headless barrels were placed one on another from the bottom of the well to a height of two or three feet above the surface of the ground. The earth is packed in around the cylinders, and they last a long time. In some cases the well has a stone or cement top, but this is more for ornament than because it is of any value.

The connection between the pipes and the wells is formed by bamboos about two inches in diameter, out of which the septa have been broken. The depth of these wells seems to depend only on the quantity of water which is used from each well. The discharge through the bamboo tube is about uniform through the day, and is of course very small; so the well must contain a considerable part of the supply for a day; otherwise some of the users might have to wait for the water to run in. The wells are so slowly filled that in case of fire they are quickly emptied; the waterworks are consequently of but little value in extinguishing fires. Each well is usually surrounded by a narrow platform on which the rice and clothes of the neighborhood are washed.

The mains are carried across the canals by suspending them under the bridges. The bridge across the Kanda river, spoken of above, is a wooden box about four feet square, which reaches from bank to bank. It is about sixty feet long, and is supported at two points on piles. A grating placed at the entrance serves to arrest any floating body which may come down the Kanda canal.

The systems of pipes spoken of supply only that portion of the low part of the city which is west of the Sumida river, and only those districts in the high part of the city through which they necessarily go. On the eastern side of the Sumida there are no mains; and, as the water in the wells is brackish, drinking water is brought in boats from the mains on the western side of the river, or from the rivers at points above the limits of the tide. It is sold in the streets by the pailful at about one-eighth of a cent a gallon.

In order to appreciate the difficulties which the Japanese had to overcome in building these water works, we must take into consideration the tools with which they did the work. They did not have shovels, carts or pickaxes in making the excavations. To dig the earth they now use a long narrow hoe, the head of which is wood protected by a heavy iron edge and sides. If they wish merely to throw the earth out of the excavation, they first loosen it, then hoe it into a shallow basket, and then lift or carry the basket out and empty it. If they wish to carry the earth some distance they hoe it on to a mat, the diagonal corners of which are connected together by ropes; a pole is passed through the ropes, and two men, taking the pole on their shoulders, carry the earth away.

In making the pipes they must experience considerable difficulty, as the long slender spikes used cannot be driven, and they have no augurs. They use a tool which is especially made for driving in and pulling out again, and with this, after driving it in and loosening it several times, they get a hole so deep that the spike may be driven in its full length without bending.

The Tama canal is 28.9 miles long and has connected with it in the city 30.3 miles of pipes: the Kanda canal is, with its branches, 14 miles long, and has 29.1 miles of pipes. The pipes are connected with 8,000 wells.

In 1877 an examination of the water at various points in the city was made by Prof. Atkinson (see Transactions of the Asiatic Society, vol. 7, 1877). He found that the water, when it entered the city, was very pure; but that, as it ran on through the pipes, it was more and more contaminated, until, in the lower and most thickly settled part of the city, it contained a large percentage of impurities. The presence of these impurities might be explained either by a leakage of surface water into the pipes, by diffusion through the pipes, or by the flowing back into the pipes of water which had become impure in the wells. The last explanation seems to be most satisfactory, as the surface water in many cases does make its way into the wells, and there must be a re-discharge back into the pipes, during the hours when there is the greatest call for water, from those wells from which but little water is used.

The water works of Tokio cannot be cited as an example of what such works

should be; they are interesting only as a specimen of engineering executed long ago, and wholly under Japanese supervision. At present they exhibit great defects, and doubtless before many years they will be replaced by a new system embodying all the improvements made in other countries, and spreading over the whole extent of this great city.

ARCHITECTURAL METAL-WORK.*

By T. W. TONKS.

From "The Building News."

THE very position of a nation is held to be shown by how many thousand miles of iron rails it has laid down in comparison with the square mileage of its area; it is tested by how many millions of tons of iron it can produce annually, or by how many it can consume in its manufactures. The very rise or fall of a nation's prosperity is now gauged by the rise or fall of its production or consumption of iron, or by both taken together, and the rise or fall of many an Empire would be of less moment to the world at large than a great rise or fall in the value of iron per ton.

It was not to be expected that the architect would long remain unaffected by this potent factor in modern civilization. In the middle ages, iron had become recognized for quaint locks and quainter keys, for bolts and bars, for beautifully wrought hinges and rails. Then for elaborate gates, verandahs, furniture, and much subsidiary work; but it seems to have been reserved for the present century to apply iron in the main construction of a building. Huge girders, iron beams and supporting columns are now the rule in business architecture, and when we see the enormous weight of successive stories piled upon such slender pillars as we constantly meet in modern buildings, we are tempted to echo Mr. Ruskin's fears and warnings as to the probable fate of such erections. The adventurous spirit of nineteenth-century architecture has found in iron a fitting instrument for carrying out its wildest fancies. The Devonshire Conservatory, the Palace of Iron and Glass of 1851, the steeple of the Cathedral of Vienna, and the present Crystal Palace at Sydenham were successive achievements in this direction. Then the old stone bridge that spanned the river, with its many and picturesque arches, has given way to the marvelous Suspension Bridge, hanging almost like a fairy film in mid-air, as with the high-level Bridge at Newcastle-on-Tyne, and the Avon Bridge at Clifton. The exigencies of railway enterprise have given us many diverse instances, such as the Crumlin Viaduct and the Tubular Bridge over the Menai Straits. But, alas, in the unhappy instance of the Tay Bridge, near Dundee, we seem to have reached the limit of that adventurous architecture and engineering in iron, against which Mr. Ruskin so loudly and persistently declaims.

The dangers of corrosion and oxidation may to a certain extent be guarded against in iron construction; but there are always hidden risks arising from flaws or faults in casting, etc., which remain to be considered. It is very possible that as building construction, even in the question of the picturesque or beautiful, the single slender iron column as a support in the interiors of buildings is far inferior and but little less costly than a clustered column would be. In the early spring of last year I visited the Cathedral of Salisbury, that matchless example of the pure unmixed Gothic of England, and was struck immediately by the hint which the clustered columns of the interior gave to the architect in iron. The dark polished shafts of Purbeck marble, clustered round the lighter colored freestone columns, suggested iron in a moment by a curious association of ideas. The effect is stable, yet in the last degree graceful, and it seemed impossible to resist the conclusion that a similar cluster of iron columns, the center one

* Read before the Birmingham Architectural Association, February 24.

bolder than the rest, and not necessarily cylindrical, would be but little more costly than the single shaft. The extra cost would be more than repaid, I should opine, by the additional stability, and the relief to the eye and the mind would be enormous. Instead of the painful sense of inadequacy which the ordinary iron column conveys, the artistic sense would be satisfied by the feeling of security and delight. This plan is, I am aware, adopted in some Gothic edifices with excellent effect, but I am pleading for its more general application.

One of the uses of iron in construction, the need for which I most deeply deplore, is that of tie rods to keep together the upper walls of some churches or public buildings of any size. In the old days, when stone was the main agent in construction, and churches were built to last, the walls were sufficiently strong to stand of themselves, and not only so, but were equal to resist the storm without, and to sustain the weight of the superincumbent arch without any adventitious assistance. But now a church is built cheaply by contract, and on the conditions that it is to be as large, as convenient, and as richly decorated as may be at the smallest possible cost. The question is, therefore, how thin the walls can be made with safety. Instead of the rich mullioned windows in simple, yet sweet, stone-carved foliations at border and head of column, you have the shallow plastered arch, the weak brick divisions, the painted iron column, and simulated Gothic capital in iron casting: but, last of all, and to crown the degradation, we have the iron tie-rods across the base of the arch of the roof at intervals as you walk down the nave, and you feel that the commercial spirit has injuriously acted upon our modern ecclesiastical architecture. If congregations would consult reality rather than show, and would content themselves with more modest structures which, from foundation to roof-crest, should be thorough and lasting, the architect would have a fairer chance, and the edifice would reflect more sincerely, that thoroughness and stability of character which it is the object of religion to build up.

There is little doubt that the great development in the art of the worker in metals in the middle ages arose from the warlike necessities of the times. Not only were the weapons of warfare fashioned with the nicest regard to the services they were intended to perform, but as a man clad in a suit of armor could safely contend against many of the dangers to which he was exposed in the field, this requisite of war brought all the skill and taste of the metal-worker into constant exercise. Thus all that the craftsman could devise in the way of adaptation, and all that the artist could suggest in beauty of form or ornament of surface was brought to bear on the helmet and the coat of mail, on the sword and the firelock. An educated art-workman was thus created, and when he had done his best for the soldier, the priest was not slow in pressing him into the service of the Church. Thus we get the elaborate and beautiful locks, the door-hinges of the Cathedral, the screens, gates and rails which form so remarkable a feature of our ancient ecclesiastical edifices. It is not too much to say that this art is still among us. I hardly know a more beautiful specimen of Early English style metal work than the brass screen which has recently been executed and placed in Salisbury Cathedral by Skidmore, of Coventry. But it is unquestionably true that in proportion to the population and to the means of production of the present century, the art metal work of the middle ages was far more abundant, more correct in treatment, more delicate in expression, more elaborate and thoughtful in detail than the metal work of modern times. There is in South Kensington Museum a chair in silver repoussée, a royal chair in more senses than one. In addition to the beautiful proportion of its various parts and tender propriety of its lines, it is divided into compartments of surface by rich and suggestive ornament. Each compartment, of which there are a great number, contains a bas-relief. The bas-reliefs, all charmingly executed in repoussée, depict a genealogy, commencing with Adam and Eve in the Garden of Eden, going through a large portion of the history of the Bible, and lastly branching off into some fabulous pedigree, connecting all that preceded with the history of the country and of the king in whose reign the princely seat was fashioned. You may probably agree that there is

much redundant effort, an excess of luxury, and some undue flattery in all this. It is not likely that an order for such a Chair of State would be given by any potentate in Europe to-day, nor is it desirable that there should be. Yet this is an instance, an extreme one if you will, but an instance of the great perfection to which the art of the metal-worker had attained in an age otherwise dark, and in many respects lacking the knowledge and opportunity now possessed by the civilized world. The excellence of hand and eye which had then been obtained by the worker in metals was, however, in unison with, and walked hand in-hand with the architecture of the time. The style of the Chair of State was the style of the hall of the palace in which it was a central ornament. As you entered the Cathedral and noted the exquisite tracery of the lock, you saw that it had much in common with the tracery of the windows and of the roof. Every touch of the worker in metals was, in point of fact, in harmony with the building for which his work has designed, and this consideration brings me to the central part of my subject.

It is my misfortune to pass nearly every day on my way to business a hideous mass of bricks and mortar put together on strictly commercial principles. I had said bricks and mortar, but I should have said wide columns of bricks and mortar supported on narrow square-moulded columns of cast iron, having between them successive rows of glass-covered apertures dignified with the name of windows. I must premise that in one or two of the apertures in the lower row, doors were inserted, and when I have said there is a roof, I believe I have sufficiently described a piece of utilitarianism which illustrates the full and complete avoidance of every principle of art. This may be another extreme instance, and the Chair of State of the middle ages on the one hand—the cast-iron columns of this midland erection of the year of grace 1880 may be taken as the opposite poles in metal work. It is a sad confession that the contrast is not in favor of the present day; and this directs us to the singular tendency in this respect of modern architectural progress. Now the architect, as a necessary part of his education, must be somewhat of an engineer. His knowledge of iron must be important and varied. He must understand the supporting power of an iron column as compared with that of stone, brick, wood or other material. He must gauge the relative capacities of endurance and resistance of iron, and its cost in each case as compared with other means of construction. The utilitarian element must be studied carefully by him, and every new principle or mode of metal construction economically applied, or he will be in danger of being passed in the race for success by men perhaps otherwise of far less capacity. All this the modern architect must do, all this he will do, in spite of the denunciations of art-critics. Though Mr. Ruskin may inveigh against this feature of the iron age, and though we may own with regret the justice of many of his positions upon this subject, yet all this will not advance the question much. The architect is, after all, like every other professional man, the servant of the public, and though he may within certain limits guide and help the public in the way of taste, yet the public will always determine for him that very important question, the limit of expenditure upon a given building. And if the public is keen upon any points affecting the architect, it is upon the economical construction of a building. To obtain the best accommodation for the lowest price, to have as little wasted space as possible, to carry the greatest weight at the smallest cost, and to have as much light and as much window frontage as the land will allow; these are the needs of many clients, who, though ignorant or careless of all else, must be satisfied upon these points. The architect must meet these demands. He is helpless to refuse the conditions offered him, because if one architect does so refuse, there are a dozen others who will gladly comply with them. What, then, can he do? In the answer to this question lies, I conceive, the measure of the influence which the architect is able to exert upon his time.

I have said that the architect may, within certain limits, guide and help the public in the way of taste. He can do so in the first instance, by complying with the demands of the public, but, nevertheless, in all his work giving a bearing in the direction of true art.

When Haydon, the painter, set up his theory, no doubt a correct one, that a great historical art was altogether wanting in this country, and then, in pursuance of his theory, set to work painting such pictures of proportions to which no buyers could be induced to respond, we know that he made a serious, a fatal mistake. But when the late E. M. Ward, R.A. (whose end, alas! was equally sad, though probably from very different causes), painted historical pictures with a finish and of a size suited to the dainty dining-rooms or galleries of the British merchant and manufacturer, his success was at once assured. The lesson should not be lost upon the British architect. Without a Quixotic tilting at all the windmills of phantasy which a non-professional critic can fairly indulge in, the designer of a public or private building, if he has the correct aim in view, and if he has a genuine love of his art, can carry out the wish of his patron or client, yet always with a determination to make the edifice better, truer and purer in style than his uninformed proprietor could have expected.

The old Italian conception of the architect was that he was a "Grande Maestro," a complete supervisor as well as designer of a building, and thus that he must have complete control of the construction from beginning to end. In the days when artists like Leonardo da Vinci and Michel Angelo were architects, this title was no empty name, and while the outlines of a building were traced by their decisive pencils, many of the details, and notably more of the decorations, were finished by their own hands. It is not, of course, to be expected that this could be the case in these modern days. The complexity of life is so vast and intricate, the division of labor is so complete, that a man can only attempt to know and understand one thing well. But the one thing that the architect should know well is the way in which the conception or idea of a building should be carried out even to its veriest details. If the architect realizes the spirit of his calling, he should not be satisfied when he has supervised the erection of the mere shell of a building. If he leaves the decoration of the interior to others, who can say but that the mere decorator will lose altogether the essential beauty of the style in a crowd of inharmonious details? I may say, in passing, that I consider the effect of the new Council Chamber in Birmingham is seriously injured from this very cause. If, again, the architect leaves the decision as to all the minor ornamental metal-work to others, the same result will probably ensue. This will be the more unfortunate, as with the necessity now existing for plain, simple, economical construction, the only special opportunities the architect has after the general form and proportion of the front elevation has been decided, consist in the ornamental metal-work, and small decorative features. The grill ornament upon the summit of the roof-line, the spouting, ridges, locks, hinges, palisades, and gates are often the only saving clauses he can be allowed to expend his taste and knowledge of style upon, after the huge block of commercial buildings has given its additional mass of shadow to the crowded thoroughfare. Here, therefore, at least, art may blossom, and if the architect is indeed the "grande maestro" he will not be satisfied until some at least of the plainness and simplicity of the modern fabric is warmed into beauty by the sympathetic touches of his ornamental metal work. What is thus too often left to chance or caprice will become to him an important vehicle for conveying that sentiment of taste and fitness which every true architect will desire to reflect in his work. Gutters and spouting, which are now either concealed or left in their naked ugliness of line, as necessary blots upon the building, or as nuisances that cannot otherwise be got rid of, would be turned to true artistic purpose, and made to assist and beautify the effect of the edifice to which they are attached. In the same way, the manufacture of locks and hinges, instead of having become mere specimens of mechanical utility, holding their own with resolute economy of construction against American competition, might again become a fine art. There is no room to doubt that if the modern architect turned his attention earnestly to this subject, we might have the great art-period of the lockmaker of the middle ages restored.

In saying this, I do not mean to infer that such art does not exist now. I believe it does exist, and we have all evidence indeed that when any specially beautiful work of this character is re-

quired, and when a heavy price can be paid for it, such work, equal, nay perhaps superior in some respects, to the fine metal-work of the middle ages can be produced. But these are essentially products of luxury, so much out of proportion to the relative cost of such examples in past times, and so much beyond the economical needs of ordinary building construction, that they can hardly be expected to become general. The difference between these old metal-workers and the present is that the former had a real pride in and love for his art, that he worked on true principles with some knowledge and taste, and that whether by his own sense of fitness, or by the design of the architect we cannot now always determine, but by some cause or other his productions always harmonized with the buildings to which they were attached, and assisted in the unity of the leading idea of the style. This appears to have been the rule with the ordinary metal-worker of the middle ages; with us moderns it is the exception. We know there are men, and great art-manufacturers who fully answer to this description; but what of the mass of workmen? Are they not a reckless crowd of Cyclops kind, with one eye only to their work, and that fixed upon it with a view only as to what wages it will bring? The mere mechanical requirements which have been deemed essential have been satisfied in this manufacture, and as little else is asked for by public or by architect, nothing else is given. But there is every reason to believe that, if the professional educated class who are expected to guide the taste of the public in the matter of building construction in Great Britain—if this class will only rise to the occasion and assert its right to superintend and improve these details—a great change will take place. The needs of art-education, both for masters and workmen, are now fully recognized, and though many blunders are being made in the steps taken to remedy this state of things, all these efforts are in favor of the architect, who knows what he wants, and who desires to have metal work to harmonize with his designs. A general demand for art in architectural metal-work will certainly, in time, bring about an adequate supply. What is more—an educated metal-worker will in a certain period be built up, and those beautiful specimens of art-work, which are now the luxuries of private palaces or public buildings, will become the natural and frequent adornments of even ordinary streets. What is now so costly will be brought within reasonable limits of price, not because the workman is reduced to wages just above starvation level, but because his educated hand and eye enable the average artisan to execute with pleasure and profit what he now cannot conceive or execute at all. This is, to my mind, one of the most important considerations which should weigh with the architect in taking the subject up, and it is one which should encourage him to persevere in asserting his right and privilege, to make the metal-work of his buildings the delicate finishing touches which shall emphasize and vitalize the principle of design he has embodied.

It is a good feature of the Bethnal green Museum that the authorities of South Kensington have gathered together a large number of specimens of architectural metal-work, and have arranged them so that they can be there studied with advantage. The next thing which is desirable is that every great manufacture center for metal-work should have its branch exhibition, either supported by important loans from South Kensington, or, still better, by grants of specimens of the kind specially suited to the trades of the locality. The first principles of fitness of style will then be learned by the ordinary worker in metals; and then, if the architect keeps the important end in view, the true idea and practice of finish will follow. The malleability, the pliability of metal, the exquisite delicacy to which it can be wrought, all adapt it to the purpose of the architect who desires to relieve the heavy masses of his edifice with the tenderest touches of beauty. Mr. Ruskin, in one of his books (I forget which, for the moment), describes a front of Italian verandah, in hammered iron, in the center of which a bouquet of flowers was wrought with such grace and sweetness that he avers he has seen nothing comparable to it in modern work. The old gates of Hampton Court, designed and wrought in the 17th century by Shaw, of Nottingham, and now a portion of them at Bethnal-Green Museum, are studies in the much-discussed style of Queen Anne.

THE THEORY AND CONSTRUCTION OF THE LEADING FORMS OF ELECTRO-MOTORS, AND THEIR EMPLOYMENT IN THE PRODUCTION OF THE ELECTRIC LIGHT.*

By Prof. HENRY MORTON, Member of the Light-House Board.

In whatever way electricity is to be used as a source of light, there is, of course, no question that a cheap supply must be found in order that it may compete with other means of illumination. As long as the galvanic battery was the only instrument for producing electricity, we were met at the very start by the following state of facts:

The source of energy in the battery is practically the zinc consumed. Weight for weight, coal has almost six times the available energy of zinc; while, moreover, the price of zinc is about 25 times that of coal. In the race between the two, therefore, zinc starts with this enormous disadvantage, that an equal amount of energy obtained from it will cost about 150 times as much as if obtained from coal. To make gas from coal and burn it for light will then be cheaper than to obtain electricity from zinc and turn it into light, unless the loss in the former case is 150 times greater than in the latter. Batteries, therefore, as sources of electric force for lighting purposes, are out of the question from an economic standpoint.

The possibility of economic lighting by electricity came first to exist when, in 1831, Faraday discovered that the motion of a magnet in relation to a conductor would develop a current of electricity in the latter, and thus that electricity might be developed by the expenditure of mere mechanical energy.

The first principle involved in this subject is this:

Magnets exert forces in all directions around them, but in such a way that they may be said to be surrounded by "fields of force," in which the forces are distributed in certain directions, known as "lines of force." Some notion of these is obtained if we place a plate of glass over a magnet and then sprinkle iron filings on the former, when on tapping the glass the filings will arrange themselves in certain lines.

A very beautiful method of arranging and permanently fixing such lines has been devised by Prof. A. M. Mayer, and from plates so arranged by him, Figs. 1, 2, 3 and 4 have been produced by a process of photographic engraving.

Fig. 1 shows these lines of force as they are arranged about a single straight bar magnet with its north pole at one end and its south pole at the other.

Fig. 2 shows the arrangement of these lines of force when two bar-magnets are placed side by side, the opposite poles being adjacent. In this case the lines of force run across between the ends of the bars, making a very intense magnetic field at these places.

Fig. 3 shows the arrangement of the magnetic curves about a pair of bar-magnets placed parallel to each other with their like poles together. Here the lines of force do not run across between them but are bent around parallel to the length of the bars.

Fig. 4 shows the lines of force about one end of a magnet bar and a small piece of soft iron in front of it magnetized by induction from the large magnet.

It was discovered by Faraday, in effect, that whenever a conductor was so moved in the vicinity of a magnet as to pass through or "cut" these lines of force, a current was developed in the conductor. The greatest effect was obtained when the lines were cut at right angles, and when the greatest number of lines are cut in the same time, either by passing through a denser "field of force," as near the poles of the magnet, or by moving more rapidly. When the conductor moved *along* the lines of force no current was produced.

As the conductor passed into and through the "field" of one pole a current was developed in one direction, and as it passed out of the same field into and through the field of the other pole a current in the opposite direction was devel-

* Abstract from "Reports on the Topophone and the Electric Light," by Prof. Henry Morton, Member of the Light-House Board.

oped. Between the two fields there would, of course, be a neutral point where no current is developed. Indeed, if we turn to Fig. 2 we will see that a conductor, while passing the center of the magnet, would be moving along the lines of force, and ought, therefore, to develope no current, while near the poles it

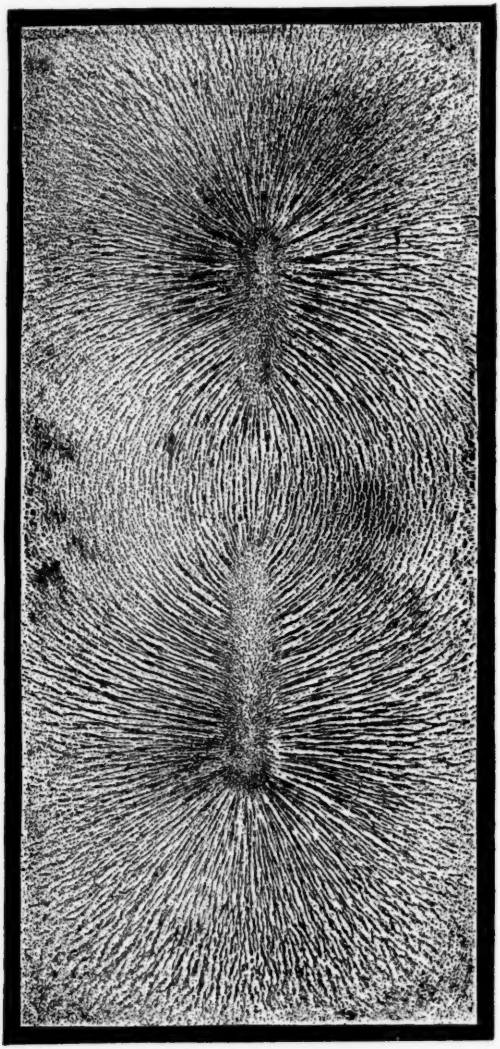


Fig. 1.

would pass at right angles to the lines of force, and so give a maximum current. At other parts of its path the conductor develops currents of more or less intensity, according as it finds the lines of force more or less oblique to its path.

While the above basis of explanation is very commonly employed in connec-

tion with our present subject, there is also another which I shall now proceed to state.

In the first place, it will be desirable to indicate the relations between magnets and electric currents first pointed out by Ampère.

According to this theory, a magnet owes its characteristic properties to the presence in the molecules of electric currents all circulating in the same direction.

In other words, if Fig. 5 is supposed to represent a short magnetic bar with its

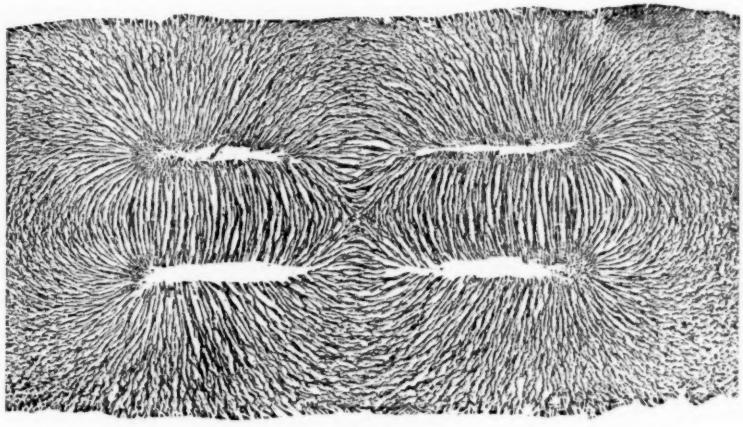


Fig. 2.

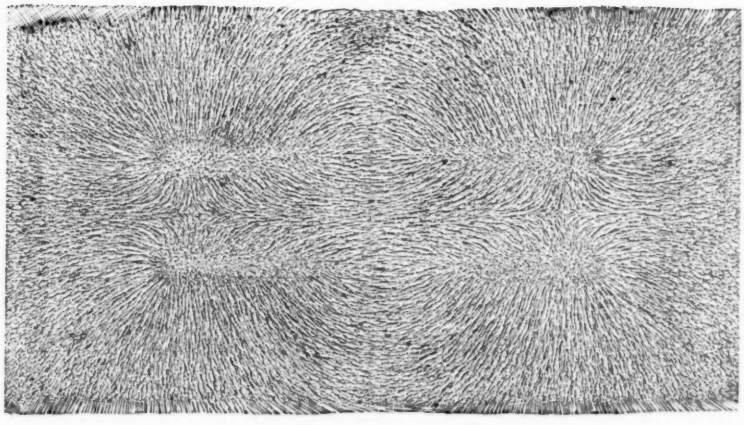


Fig. 3.

south end towards us, the little arrows would represent the direction in which the currents of positive electricity were flowing in its molecules.

The general effect of such currents could evidently be expressed by single currents passing in the entire bar, as indicated in Fig. 6, and the practical effect of such a series of parallel currents would very evidently coincide with that of a current passing through a helix, as indicated in Fig. 7.

As a matter of fact, we find that a helix of wire, through which an electric current is flowing, will exhibit all the properties characteristic of a magnet. Thus, it will

attract iron, if freely suspended, point north and south, and if two of such helices are brought together their like ends will repel and their unlike ends attract each other.

This attraction and repulsion, moreover, appears to come under a still wider law, for it may be readily shown that any parallel electric currents, if going the same way attract, and if going opposite ways repel.

Fig. 8 shows how this explains the attraction of unlike and repulsion of like poles in magnets.

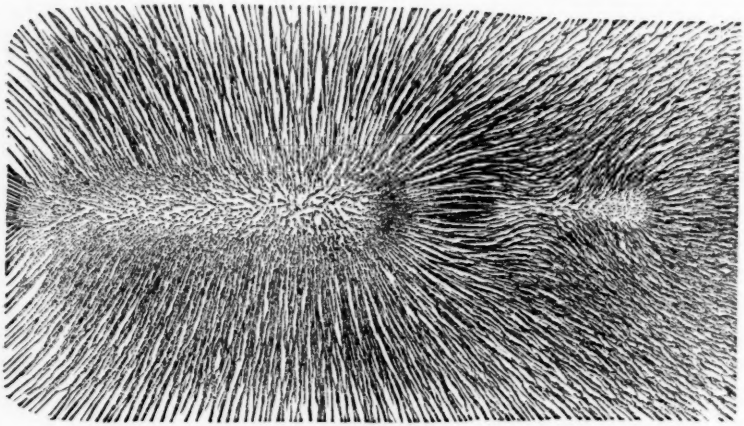


Fig. 4.

In A and B, the north and south poles being opposite, the magnetic or electric currents flow parallel and in the same direction, and thus attract, in A′ and B′, the two north poles being together, the

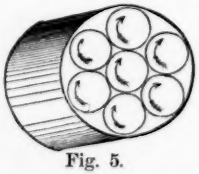


Fig. 5.

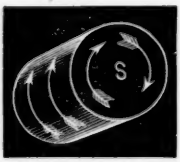


Fig. 6.

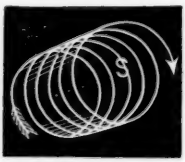


Fig. 7.

currents flow in opposite directions, and thus repel.

Another general law must next be stated, namely: Whenever a conductor approaches a parallel current, a momentary flow of electricity is established in the said conductor, opposite in direction to that of the current towards which it is moving; as the same conductor recedes from the current a momentary flow in an opposite direction is produced.

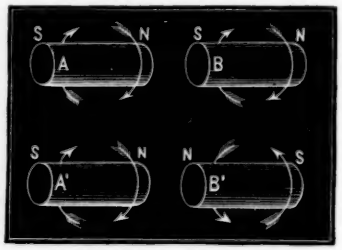


Fig. 8.

Let us see how this applies in such a case as we have now to consider.

Let N S, Fig. 9, represent a magnet in which the magnetic currents are flowing as indicated by the arrows on the bar; if, then, we bring a conductor, like the loop of wire to the right, towards the south end of this magnet, a current will

be developed in the loop opposite to the currents in the magnet, because the loop is approaching all of them. If now the loop continues to be moved forward over the S end of the magnet, when it comes over, say, the point *n*, it will still be approaching many of the magnetic currents, but will be receding from a few, those namely, which it has already passed. There will, therefore, be an interference between the opposite currents due to the approach to the magnetic currents to the left, and the recession from those to the right, and the resulting current will, therefore, be feeble, although still in the first direction.

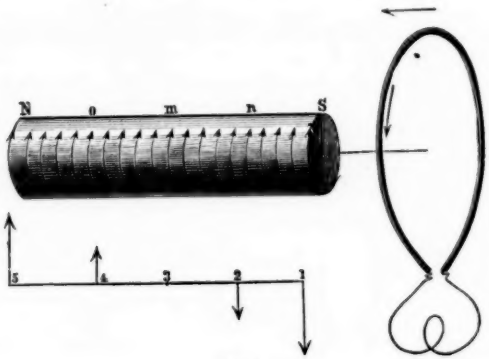


Fig. 9.

When, however, the loop comes over *m*, the number of magnetic currents it is leaving is just equal to that of those it is approaching, and the two currents will, therefore, be exactly neutralized.

Beyond *m*, towards N, however, the current due to the withdrawal from the magnetic currents will predominate and increase until the north end of the magnet is passed.

The horizontal lines with vertical arrows, at the lower part of Fig. 9, repre-

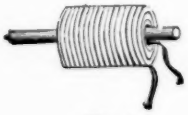


Fig. 10.

sent the directions and relative intensities of the currents developed as the loop moves over the magnet from right to left.

It will be readily understood that it is quite immaterial whether the conductor is moved over the magnet or the magnet is moved through the conductor.

Thus, if the conductor is wound into a coil, as in Fig. 10, and the magnet is pushed into or drawn out of it, we shall have a like production of currents.

Or again, if the coil should have in its center a bar of soft iron, and this should be magnetized by the approach of a magnet, and then lose its magnetism on the withdrawal of the same, this will be equivalent in effect to the sudden insertion and withdrawal of a magnet.

The first attempt which was made to utilize the above-described principles in producing a current of electricity from a magnet by the expenditure of mechanical energy was that by Pixii, of Paris, who, in 1832, produced the apparatus shown in Fig. 11.

Here two coils of wire, with soft iron cores, are supported at the upper part of a frame, while below them a strong steel magnet is made to rotate by appropriate machinery. As each pole of the magnet in turn comes opposite the iron core of either coil, it renders it instantly magnetic, and thus develops a current in the surrounding coil. These currents, of course, are alternately in opposite directions, and to correct this a "commutator" is placed below on the moving shaft, which, by reversing the connections at the right moment, sends the currents al-

ways in the same direction through the exterior wire.

Saxton, in Philadelphia, made, in 1833, a modified form in which the steel magnets were placed horizontally, and remained at rest, while the coils with their soft iron cores were rotated opposite their ends. Various small modifications followed. Thus, in 1836, Clarke, in London, made a machine represented in Fig. 12, in which the steel magnet was made of several single magnets united, and the coils were rotated opposite the poles, but at right angles with the plane of the magnets.

Again, Breton wound coils on the poles of the magnet, and then rotated an armature in front. This armature, by its approach and withdrawal, caused movements in the lines of force, or in the magnetic currents, which developed momentary currents of electricity in the coils of wire. The relation of this action to Brequet's apparatus for exploding mines, and to the Bell telephone, is worthy of notice.

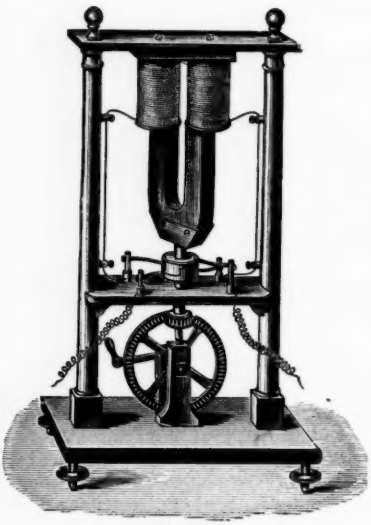


Fig. 11.

Duchenne combined this last plan with the preceding one by winding coils both on the magnet and the armature, and using one or other of the circuits for his induced current.

The first attempt to make a magneto-electric machine of such a size as to be available for industrial purposes, was made in 1849, by M. Nollet, professor of physics at the Military School at Brussels.

The original intention of those first engaged in developing this machine was not, however, to produce with it an electric light, but to employ it to *decompose water in order that the hydrogen so liberated might be used as an agent of illumination.* If we were in want of an illustration of the extravagance and irrationality of expectation which so often exhibits itself in enterprises entering upon new fields, we surely need go no further than this. M. Nollet died before his designs were entirely carried out;

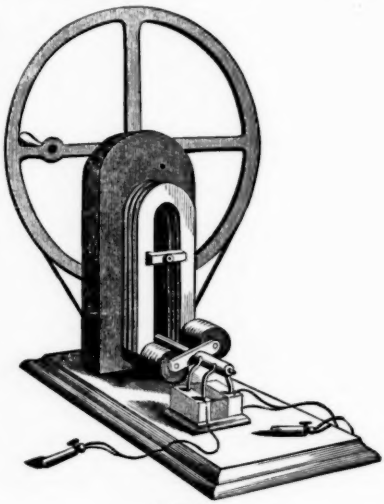


Fig. 12.

but they were elaborated by an intelligent workman who had assisted him in the construction of his machines, M. Joseph Van Malderen, who, under the auspices of a company composed of French and English capitalists, and named the "Alliance Company," developed the apparatus into an efficient generator of electric currents for the direct production of light by means of the electric arc.

The apparatus, as thus constructed, was, in general principle, only an enlargement of the Clarke machine, and consisted of a large number of

compound steel magnets, between the adjacent sides of which cores of soft iron, surrounded with coils of isolated wires, were made to revolve. An appropriate connection of these various coils with each other, and with commutators on the axis, enables the current to be taken off in a constant direction. When it was afterwards discovered that, for an electric light, the current need not be constant in direction, but was even more convenient when rapidly alternating, this was of course yet more easily provided for. Fig. 13 shows one of these Alliance machines, which really needs no further description, its structure and operation being rendered perfectly clear by the cut.

Many of these "Alliance machines' were made and used in different places

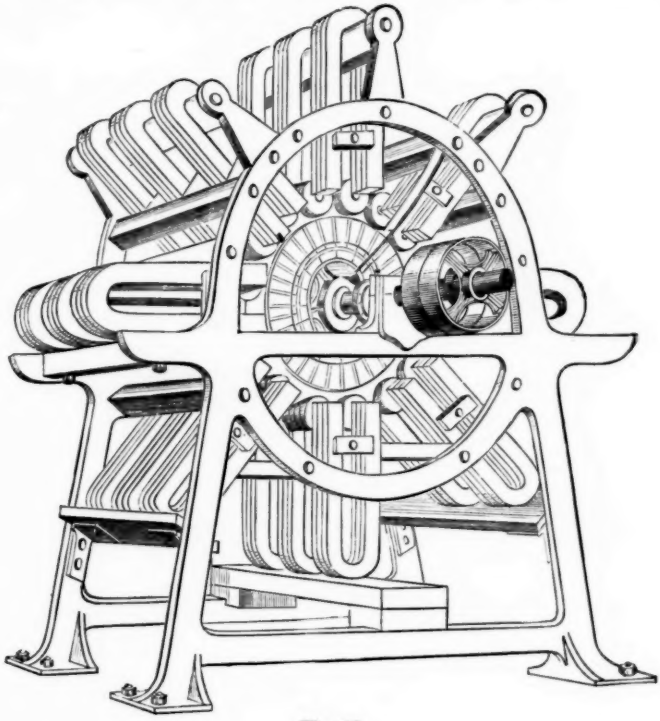


Fig. 13.

in France for lighting works of construction at night, such as the Cherbourg docks, and on some vessels, as the Lafayette and the Jerome Napoleon, and in some light houses; and, as modified slightly in arrangement of parts by Mr. Holmes, in England, notably in the South Foreland light house.

The great cost of these machines, the large amount of power required to run them, and the cost and trouble of keeping them in repair, however, limited their use to a very narrow field, and they could hardly be said to have carried the subject of electric lighting beyond the range of an interesting scientific experiment on a large scale.

The next important step in the development of the magneto-electric machine consists in the application by Dr. Siemens, of his peculiar armature to these instruments.

This armature is shown in longitudinal section in Fig. 14, at E, and in cross section at F.

The armature is in fact a rod or bar of soft iron, with deep grooves cut lengthwise along it, reducing its section to an

H form, as is shown in F. Insulated wire is then wound lengthwise in these grooves, as shown in E. Such an armature as this, mounted with caps, as shown in Fig. 14, may then be rotated in a very narrow and dense magnetic field, and its wires will cut many lines of magnetic force in a short time by reason of their rapidity of angular movement, being close to the axis of rotation.

Fig. 14.

This armature was first used in magneto-electric machines employed for telegraphing by Siemens in 1857.

The next advance, and this a very marked one, was made in 1866, by H. Wilde, of Manchester, who, on April 13, communicated to the Royal Society the result of a series of experiments with magneto-electric machines, of which Fig. 15 is a good representative.

In this machine a number of small horseshoe magnets are so arranged that a Siemens armature may be rotated between their poles.

The coils on this armature have developed in them, by moving in this highly concentrated magnetic field, a very powerful current. This current is then passed through heavy coils of wire surrounding the sides of a large U magnet, made of massive plates of wrought iron. Between the poles of this rotates another Siemens armature of larger size, from which a current of immense power is obtained.

While the electric current developed by this machine far exceeded anything

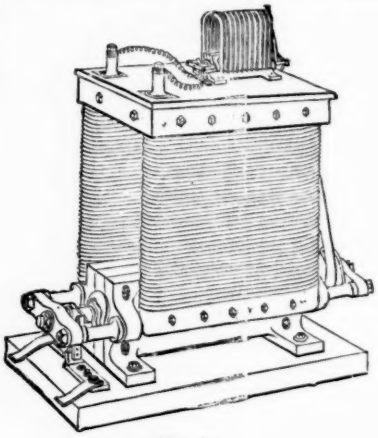


Fig. 15.

which had ever been obtained before, it was only secured by a large expenditure of power—something between a five and

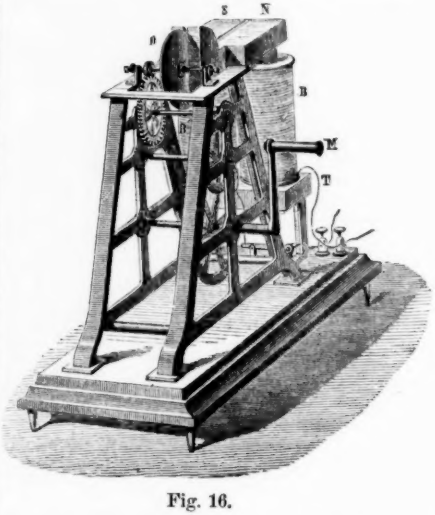


Fig. 16.

a twenty horse-power engine being required to drive it.

The important fact developed by Mr. Wilde in this machine was that a magneto-electric machine could develop a

current whose magnetizing power was vastly greater than that of the magnets from which it was derived. Thus, if the small magnets above would lift a weight of 50 pounds, the large electro-magnet below, when excited through their instrumentality, would lift 500 pounds or more. This possibility of a sort of magnetic accumulation of growth was a demonstration of immense value to the progress of magneto-electric science.

A practical difficulty which first showed itself in a conspicuous degree in these very powerful machines was the heating of the armature. Foucault had first shown, long before, that when a conductor was rotated or moved in a magnetic field it became strongly heated.

His apparatus to illustrate this is shown in Fig. 16, where a copper disc is rotated between the poles of a powerful magnet, and becomes very hot.

Tyndall, by similarly rotating a copper tube, melted the fusible metal with which it had been filled.

The heat developed in the armatures of Wilde's large machine was so great as to cause serious inconvenience, and of course involved a great loss of effect or waste of power.

In 1867 Siemens proposed a very obvious modification of this machine of

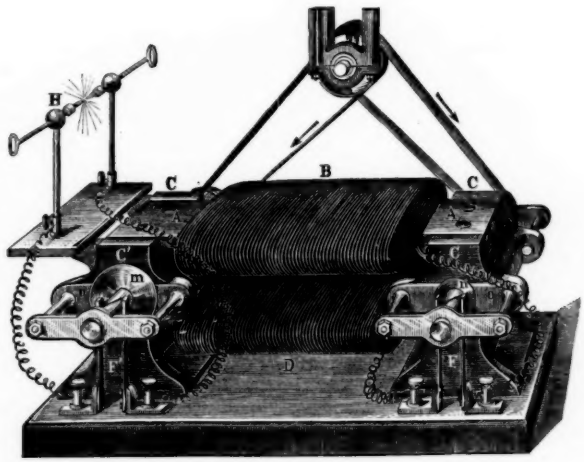


Fig. 17.

Wilde, by dispensing with the smaller machine and connecting the coils of the large one with its own armature through the commutator of the same. The residual magnetism of the iron of the electro-magnet was found sufficient to start the action, which then increased by self-development.

This, however, occasioned what was at first regarded as a serious difficulty.

If the magnetism of the electro-magnet was thus made to depend on the current of the machine itself, any interruption in the flow of the same in the exterior circuit at once cut down or destroyed this magnetism, and so reduced the whole action.

To obviate this, Ladd, of London, first made a machine with an armature wound with two coils of wire, one being connected with the magnet of the machine, and the other with the exterior circuit.

Afterward he made a machine in the form shown in Fig. 17, where two armatures were used—one connected with the coils of the machine itself, and thus supplying what is often called the "field of force," the other supplying the exterior circuit.

Subsequent experiment has, however, shown that the arrangement is very far from economical in the conversion of energy, and all the machines now in use include the exterior circuit and the field of force in one continuous connection.

This, of course, greatly complicates

the relations, and makes the fluctuations during running greater and more numerous; but for the sake of efficiency or the economy of expended power, it has been found essential to adopt this arrangement.

PACINOTTI'S RING MACHINE.

The first magneto-electric machine for the production of an electric current continuous in character and constant in direction and intensity was that devised by Dr. Antonio Pacinotti in 1860, and constructed by him for the physical and technological cabinet of the University of Pisa. A description of it, however, did not appear till several years later, in the June, 1864, number of the Italian scientific periodical, "Il Nuovo Cimento." This number, which was published during the month of March, 1865, contained an extended illustrated description of the machine.

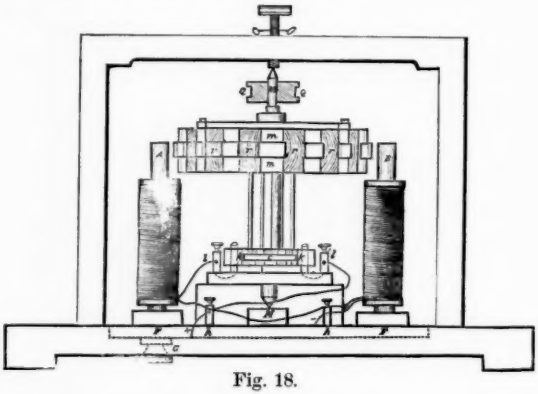


Fig. 18.

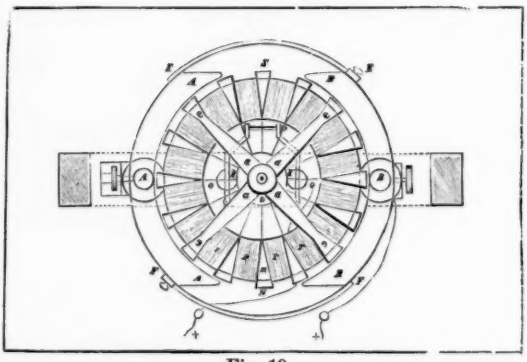


Fig. 19.

As a special feature of the apparatus he pointed out the peculiar form of the movable electro-magnet—a circular iron ring in which, contrary to the case with the armatures previously in use, the magnetic poles did not remain stationary, but could be moved within the ring—that is, made to assume in it successively all possible different positions.

This movable ring of iron had the shape of a spur-wheel of 16 teeth, and was firmly secured to the axis of the machine by means of four strips of brass. Small wooden wedges were placed upon the teeth of the ring, and the space so formed between each two of the wedges filled up regularly with insulated copper wire. These spools were all wound in the same direction, and the terminal end of each was soldered to the beginning

of the one succeeding it, so that the whole system of 16 spools virtually formed a single coil of wire surrounding the ring in a regular manner, and returning upon itself.

Wires were soldered to the separate points of juncture and were led, parallel to the axis of rotation, to an equal number of insulated pieces of brass, mounted in two rows upon, and slightly projecting from, the surface of a disk firmly secured to the axis.

The iron ring, with the bobbins wound upon it in the manner already described, was mounted in a horizontal position between the two legs of a powerful upright electro-magnet, the distance of which from the ring could be adjusted at pleasure by means of a set-screw and a slot in the lower connecting cross piece. Contact rollers *k k* were made to press, one on each side of the axis, against the lower wooden disk carrying the strips of brass, so that during the rotation of the ring all of the latter were brought successively into contact with them. When, therefore, the terminal posts *h h'* are placed in connection with the poles of a galvanic battery the current will pass, supposing it to enter at *h* (+), by way of the binding-post *l* to the roller *k*, and through the strip of brass on the disc against which the roller may happen to press at the time, up to the two wire coils of the armature whose point of juncture is in connection with the strip of brass.

The current here divides, each portion passing in an opposite direction through the spools surrounding each half circumference of the ring, to meet again to form one current at the left contact roller *k*, whence the reunited current passes to the second binding-post *l'*. From here the current proceeds to the leg A of the electro-magnet, circulates around it, and, after acting similarly with regard to the other leg, B, passes back by way of the binding-post *h'* to the negative pole of the battery. Magnetic poles thus became developed in the iron ring at the points N S, the position of the contact rollers having been so chosen as to bring about this effect, and the actions of attraction and repulsion taking place between them and the poles of the stationary electro-magnet, gave rise to the rotation of the ring.

In order to turn the action of the electro-magnet upon the magnetized iron ring to the greatest possible account, Pacinotti provided the two poles with armatures, A A A, B B B, of soft iron, which were made to surround the ring very closely for over two-thirds of its circumference. Strips of brass, E E, F F, attached, served to give them greater security. In the elevation of the machine here given these armatures have been omitted in order not to conceal the ring and its surrounding spools.

The foregoing description of the ring of Pacinotti and its action has more especial reference to its application in an electro-magnetic machine, but toward the end of his article Pacinotti clearly indicates in what way, by the use of the same annular armature, the electro-magnetic may be converted into a magneto-electric machine, capable of producing, by the proper use in connection with it of a permanent or electro-magnet, a continuous current of a constant direction.

On substituting for the electro magnet A B a permanent magnet, and on rotating the ring armature, the poles induced in the ring by the proximity of the magnet will always be found at the extremtieis of the diameter passing, when produced, through the poles of this exterior magnet; so that we may come to consider the spools as alone partaking of the rotary motion, while the two semicircular magnets produced by the induction remain at rest. The current induced in any particular spool will, in the motion of the latter from N to S, preserve the direction it has on leaving N until it reaches *a*, a point midway between N and S. Here a reversal in direction of the current takes place, which new direction is preserved until the spool arrives at *b*, a point midway between S and N, where a reversal to its former direction of the current occurs, and so the action continues. The current developed in the different spools will therefore add to each other's effect, and are hence most properly collected at the points A and B, the collecting brushes coming thus to act upon the commutator at right sngles to the magnetic axis of the rotating arma ture.

Pacinotti did actually obtain an uninterrupted current of constant direction on causing the opposite poles of perma-

nent magnets to approach the ring during the rotation of the latter. He also obtained the same effect by magnetizing the stationary electro-magnet by means of a current, though he deemed the former method preferable.

We have already drawn attention to the peculiar form of armature devised by Dr. Werner Siemens and used by Wilde in his magneto-electric machine in 1866.

A similar armature, as used by Siemens himself, in one of his earlier machines, is shown in Fig. 20.

This is, strictly speaking, a *magneto-electric* machine, as the field of force in which the armature revolves is produced by the *permanent* magnets, of a V form,

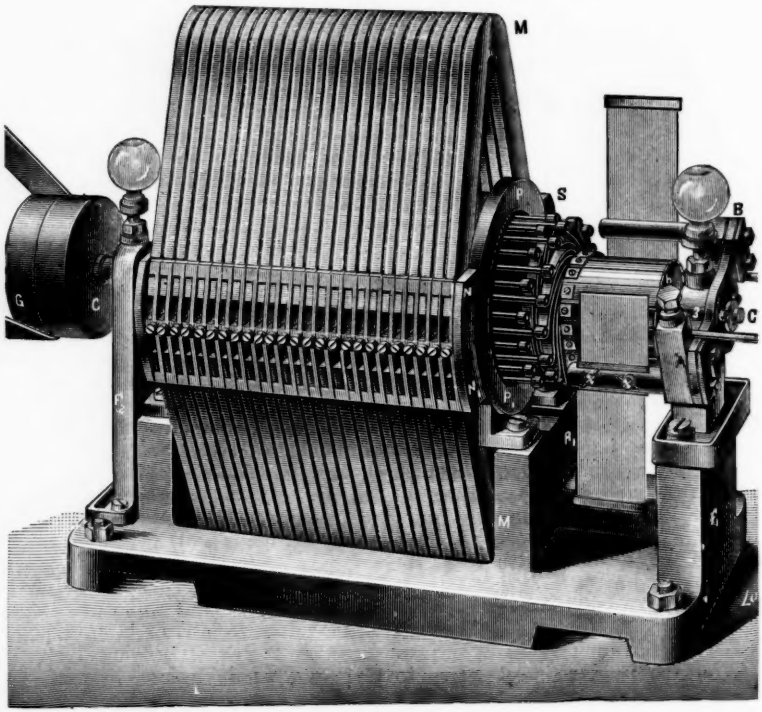


Fig. 20.

which constitute such a conspicuous feature of the machine.

Dr. Siemens was among the first, if not the first, to introduce in his machines the reciprocatory principle of passing the current from the armature coil around electro-magnets by which the field of force was developed, and his large dynamo-electric machine so arranged is shown in Figs. 21 and 22.

We can give no better description of this machine than that contained in Dr. H. Schellen's recent work, "Die Magnet und Dynamo-elektrischen Machinen," and I therefore simply translate as follows:

"We have already drawn attention to the fact that when metallic bodies are caused to move in a magnetic field, such motion develops in them induced, or so-called Foucault currents, which, if not conducted away, become transformed into heat, and thus, according to the circumstances of the case, give rise to a considerable heating of the metallic bodies in motion. As long, therefore, as the iron core revolves with the coiled

drum through the magnetic field of the exterior magnets, in the magneto-electric machine just described, these currents are not to be avoided, though they may be diminished to some extent by constructing the armature of coils of iron wire instead of massive iron. In such machines, however, which are built for the purpose of producing very large quantities of electricity, and which for this reason are constructed in accordance with the dynamo electric principle, these Foucault currents would be attended by a considerable increase in the temperature of the machine, in addition to which considerable power would be required in

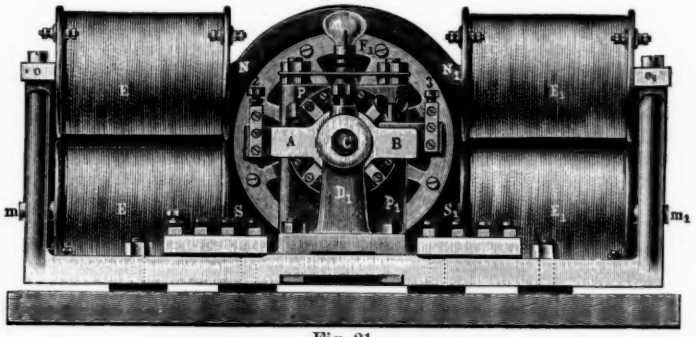


Fig. 21.

order to rotate the iron armature, owing to its becoming so strongly polarized by the powerful electro-magnets developed, for which power there would be no equivalent return in useful effect.

"These considerations must have determined the inventor to secure the iron armature inside the drum, and so prevent it from taking part in the motion of the latter in such dynamo-electric machines, like those to be used for illuminating purposes, for instance, as are intended for the production of large quantities of electricity. As a matter of course, this renders the construction and mode of arrangement of the drum much more complicated, and all the more so when it is considered that the long drum, with its surrounding coils of wire, has to be moved through the narrowest possi-

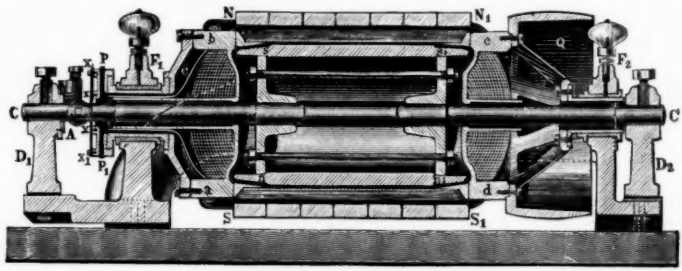


Fig. 22.

ble space between the pole armatures of the electro-magnets and the stationary inner core.

"Figs. 21 and 22 represent the construction, in detail, of such a dynamo-electric machine on the v. Hefner-Alteneck system. A horizontal section of the drum and a side view of the complete machine are there given. *a b c d* is a thin German silver drum upon which, in the manner already described, the wire is wound in many circumvolutions, and in eight separate coils. Each terminal face carries a short tube, which tubes form the trunnions of the drum, and lie in boxes, F_1 and F_2, provided with oil-cups.

An iron shaft, C C, secured by means of screws in the pillars D_1 and D_2, passes through these tubes into the interior of the drum, where the core $n\ n_1\ s\ s_1$, held together by two disks bolted to each other, is fastened upon it. The drum is surrounded on the outside at two opposite places for about two-thirds of its circumference, and over its entire length, by two curved iron armatures, N N_1 and S S_1. These are placed as closely as possible to the wire drum, and form, with the stationary hollow interior core, $n\ n_1$, $s\ s_1$, a narrow annular space, the magnetic field, through which the drum $a\ b\ c\ d$, with its surrouuding wires, must be able to pass in its rotation with all possible freedom.

"Inside of the front hollow trunnion of the drum which rests in F, there

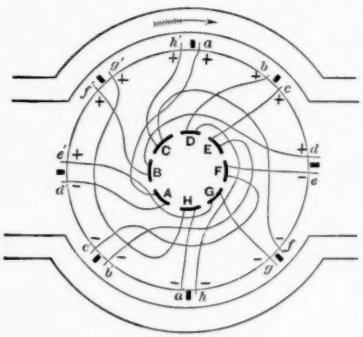


Fig. 23.

passes another hollow tube, which is secured to the end face of the drum, and between which and the trunnion the ends *ee*, of the separate wire coils, are led through to the commutator, $p\ p_1$, attached to its front end.

"The two curved iron armatures, N N, and S S, terminate in flat plates, N *o* S *m*, and $N_1\ o_1$, $S_1\ m_1$, which constitute the cores of the electro-magnets EE, $E_1\ E_1$, and through which the armatures are rendered magnetic. These cores are united at their ends by strong soft iron connecting pieces *o m* and $o_1\ m_1$, which also serve the other purpose of forming the side portions of the cast-iron frame work of the machine. Here also the wires of the two horseshoe-shaped electro-magnets, E and E_1, are wound in such a way that the poles of the same name are opposite each other, so that all portions of the iron arch uniting each set of these poles exhibit the same kind of polarity. In this way the drum and the interior iron core are surrounded for about two-thirds of their circumference, and over their entire length, by the stationary exterior magnetic poles N_1 N_1 and SS, and a very extended magnetic field formed by this means, the intensity of which will be the greater the more powerful the induced currents developed, and, in consequence, the poles of the electro-magnets, become.

"In order to carry out the dynamo-electric principle, the coils of the two electro-magnets E E and E_1 E_1, are connected with the commutator brushes, or the contact rollers, in such a way that the current generated by the machine traverses successively the wire surrounding the drum, the coils of the electro-magnets, and the electric lamps placed in the circuit. The two systems, the induced currents of the drum and the poles of the electro-magnets, exert, up to a certain maximum limit, a mutual strengthening action upon each other, which limit is determined by the wires upon the drum, the velocity of rotation of the latter, and the mass of iron in the cores of the electro-magnets."

Connections of ends of coils of armature cylinder in the Siemens machine.—The attachment of the ends of the coils to the sectors is represented in the accompanying diagram, which shows an armature of only eight coils, there being the same number of commutator plates. The two ends of the same coil are lettered *a* and *a'*, *b* and *b'*, and are connected to the sectors of the central commutator in the order shown. In following the connections it will be found that all the coils are united into a continuous circuit, the commutator sectors being traversed in succession, and the signs plus and minus indicate the direction of the circuit induced at any particular spot in the position of rotation shown in the diagram.

"In order to drive so powerful a machine, a steam engine, or other uniform source of power, will be required. As long as the circuit remains unclosed, and the two binding screws are not in metallic connection with each other, the rotation of the drum may be effected by the expenditure of sufficient force to overcome merely the friction in the journal

boxes F_1 F_2. If, however, the external circuit is closed, by the introduction of an electric lamp, for instance, the induced currents will at once be developed in the drum, if but a trace of magnetism exist in the armatures N N_1 and S S_1. These currents, by adding to the strength of the electro-magnets, exert a strengthening action upon the armatures, and thereby become themselves strengthened. The quantity of electricity generated by the machine as well as the mechanical power expended in running it, will thus rapidly become greater, since every increase in magnetism is attended by a corresponding increase in the intensity of the current. It is for this reason that, for certain purposes, in producing a *steady* electric light, for instance, a uniform action of the driving engine is absolutely necessary; and all the motors designed to be used in driving dynamo-electric machines must, on this account, be provided with reliable regulating contrivances, in order to secure such uniformity as much as possible.

"In using the machine for the production of the electric light, it may happen that, through any external cause, impurities in the carbons, for instance, the arc becomes extinguished and the current interrupted. In such a case the consumption of power on the part of the machine suddenly falls almost to zero, and a considerable (even dangerous) increase in the velocity of rotation of the drum would be the consequence thereof, were the driving engine to continue working at the same rate without having a corresponding resistance to encounter. In order to meet any such danger Siemens and Halske have provided their machine with an automatic switch, which throws into the circuit an artificial resistance when, through any cause whatever, the circuit is interrupted in the lamps. * * *

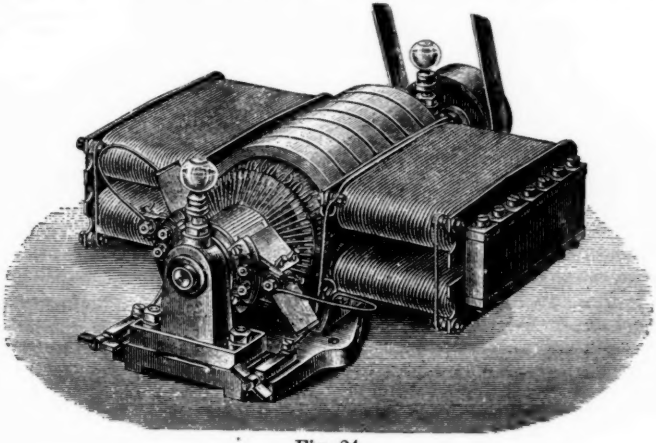


Fig. 24.

"The machine represented in Figs. 21 and 22 has a length of about 10½ centimeters, a height of 32, and a width of 46½ centimeters, and yields, when the drum revolves at the rate of 450 per minute, for which 6 horse-power is required, an electric light of 1,400 standard candles. The current produced by it is capable of heating to redness a copper wire one meter long and one millimeter in thickness.

"In the machines of medium and smallest size, in order to secure the necessary simplification in construction, the iron cylinder is firmly united with the wire coils; and rotates with them. The fixing of this inner armature, on the contrary, is rendered necessary in such cases in which there occurs a very frequent change of polarity, and in which the utmost utilization of the driving power is called for, which is usually only the case with the larger machines.

"Fig. 25 represents in perspective a Siemens-Halske machine (system of v.

Hefner Alteneck), of the latest construction. The electro-magnets have the flat shape of those used in Wilde's machine. The current is taken off by means of metallic brushes, and the large number of radial pieces in the commutator shows that the drum carries a large number of separate coils.

"In the latest machine of this form the commutator disc is done away with, and the ends of the separate wire coils surrounding the drum are connected with each other and led to the radial pieces of the drum-shaft in a somewhat similar manner to that obtaining in the Gramme machine. These radial pieces are insulated from each other by means of asbestos paper. Contact rollers no longer employed, their place being taken by flat elastic bands (brushes) made of silver-plated copper wires.

"The smaller size of these machines is 698^{mm} in length, 572^{mm} wide, and 233^{mm} high; the drum alone is 388^{mm} long, and carries 28 wire coils, and a commutator divided into 56 parts. Its weight amounts to 115 kilogrammes; the maximum velocity of the drum, 900 revolutions per minute; and the intensity of the light produced, 1,400 standard candles. One and a half horse-power is required to run it.

"The medium size differs in construction but slightly from the one just described. It is 757^{mm} in length, 700^{mm} wide and 284^{mm} high; the drum has a length of 456^{mm}, and is also wound with 28 coils; the commutator is, therefore, also composed of 56 pieces, against which wire brushes are made to press. The machine weighs 200 kilogrammes, and produces, with its maximum velocity of 700 revolutions per minute, a light of 4,000 candles. It requires 3½ horse-power."

One of these machines, of the pattern and size last described, together with an electric lamp or regulator by the same maker, was purchased by the Light-house Department at my suggestion, approved by the Board, and has been repeatedly operated under my direction at the Stevens Institute with very excellent results. The numerical expression of these results will be given in comparison with that obtained from other machines at the conclusion of this report.

Passing now to the next characteristically different machine we come to the very remarkable form known as the "Gramme Machine."

THE GRAMME MACHINE.

In 1871 M. Z. T. Gramme, a cabinet-maker, of Paris, presented to the French Academy the description of a new form of magneto-electric machine, possessing several new and remarkable features. Its general structure can be well understood from the accompanying figure, which represents one of its simplest forms as constructed with permanent magnets, and to be driven simply by hand-power.

The large U magnets terminate in heavy end pieces, which constitute massive north and south poles, almost surrounding the armature, which constitutes the peculiar feature of this machine.

Fig. 25.

This armature consists of a ring made of a coil or hank of soft iron wire, around which are wound a series of coils of copper wire, in the manner shown in Fig. 26, which represents such an armature partially dissected.

The ring made of a hank of iron wire is shown cut across and spread out to some extent, the cut ends appearing below B and at A. The several coils of wire are also represented partly in place above and spread apart in the lower part of the figure. The wire of these coils passes continuously from one to another, but between each makes a loop, which is

hooked into a copper conductor, R R, constituting part of the commutator.

The general principle on which this machine acts can best be explained by reference to the diagram (Fig. 27). Let S and N represent the poles of the permanent magnet, and the divided ring between them stand for the ring of iron wire.

This ring, under the influence of the poles S and N, will always have a north pole at *n* and a south pole at *s*, the parts *p* and p_1 being neutral, or, in other words, will correspond with two semi-annular magnets with their north poles together at *n* and their south poles together at *s*. The magnetic currents in the various parts of this ring will then be represented by the arrows drawn on it. As the ring rotates, these poles will always maintain essentially the same

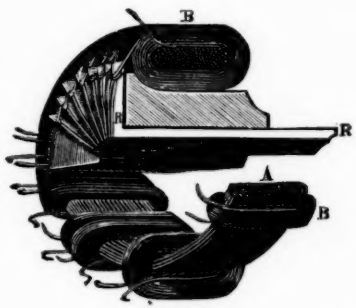


Fig. 26.

position in space, and, therefore, in relation to the coils wound on this ring, we might assume that this inner ring was at rest, and that the coils above were carried round over it.

Now let R indicate such a coil, and suppose it to move toward the right; it will evidently leave more magnetic currents in a given direction in the left-hand semi-annulus than it approaches, and will therefore acquire a current in the direction shown by the arrow, to which will be added the effect due to approaching the opposite currents in the upper part of the right-hand semi-annulus. At *n*, and also at *s*, this action will reach a maximum, as the coil will be (at *n*, for example) approaching all currents of the right-hand semi-annulus and leaving all those of the left, and *vice versa* at *s*. At *p* and p_1, however, the effect will be *nil*, as the coil would there approach and leave equal numbers of currents of like direction.

Now if we consider a number of coils all moving around from left to right, on the upper part of the ring, the currents in them will have the same direction; and if they are all connected together these currents will aid each other, and may be taken off by conductors pressing on the commutators at *p* and p_1. Let us suppose that the current is such as to make p_1 positive and *p* negative. As the coils pass p_1 the direction of the currents in them is reversed, but so also is their relation to the conductor or commutator. Thus, a coil which was coming toward p_1 from above was sending its positive current forward toward p_1; as it leaves p_1, going onward below, its current being reversed, it no longer sends its positive current forward, but sends it back to p_1, which it has passed. Thus p_1 gets not only the positive current from the coils on the upper half of the ring, but from those also on the lower half.

By reason of the action which has thus been described, there is in the first place no rapid reversal of magnetism in the iron core of the armature, as in the Wilde machine, but only a continuous and progressive change as the ring rotates; and in the second place there is a continuous current of electricity in a constant direction, with only one reversal for each revolution of the entire set of coils.

Of course the method of passing the current of one machine through the coils of an electro-magnet replacing the permanent magnets shown in Fig. 25, could be carried out with this machine just as with Wilde's; or the machine itself, being made with electro-magnets, these could be excited by its own current, as with the machines of Ladd and of Siemens, which we have already described. This last plan was, in fact, at once adopted, and the standard Gramme machine was made in the form shown in Fig. 28.

Here the electro-magnets consist of the large horizontal cylinders seen above and below, so wound with wire as to produce a combined north pole at the center above, where the extension piece

is attached, and a corresponding south pole below.

Within and between these extension pieces is the armature or bobbin, consisting of the iron ring wound with its numerous flat coils. The connections in this case are carried out on both sides of the axis, and thus several pairs of brushes can be applied, and numerous currents taken off.

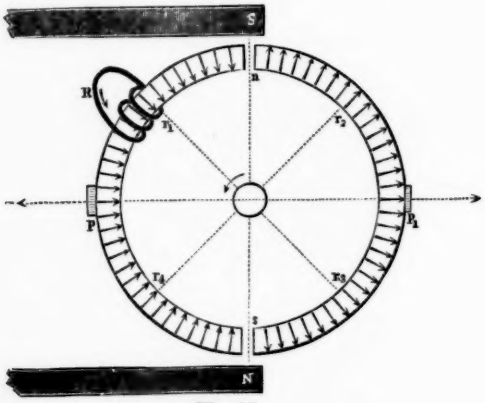


Fig. 27.

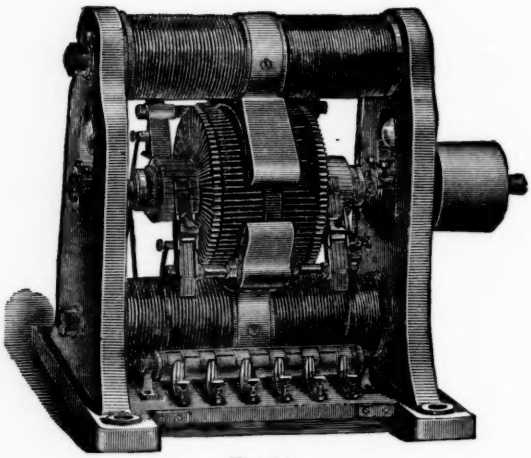


Fig. 28.

With all these machines, however, the best effects are obtained by employing only one circuit, or passing the whole current from the bobbin through the electro-magnet coils and the exterior circuit, where it is used.

In 1873 Wilde described a new form of magneto-electric machine, in which he abandoned the use of the Siemens armature, and returned, in general structure, very much to the form of the old Alliance machine.

Two sets of electro-magnets, 16 in each, were arranged in such a way that they formed two hollow cylinders opposite each other, with the poles of the magnets of each cylinder facing each other, but having space between for

another cylinder of 16 electro-magnets, mounted parallel with the others, and carried by a disc of iron, from which they projected at each side. In fact, there were three cylinders of magnets, all having a common horizontal axis; the outer ones fixed and the inner ones radiating, so as to carry its magnets between the poles of the others.

Good effects were obtained with this machine, and the heating of the armatures was avoided, but it was not found

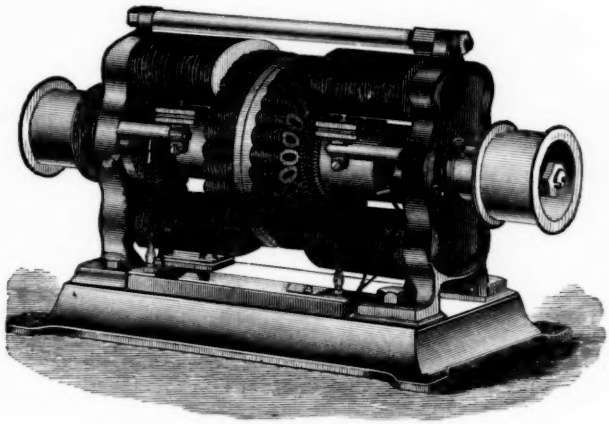


Fig. 29.

to equal the improved Siemens or the Gramme in efficiency or economy of power.

In 1875 a patent was taken out in the United States by Mr. Moses G. Farmer for a machine essentially like that of Wilde, just described. This, with some modifications of details, is now manufactured by Wallace & Sons, of Ansonia, Connecticut, and has come into very general use.

In the experiments made by the

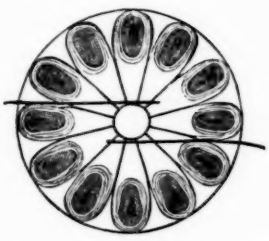


Fig. 30.

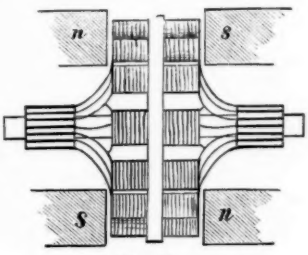


Fig. 31.

present writer, as well as those conducted by the Franklin Institute, this machine seems to be inferior in "duty" to some others; but the conditions of such trials are so difficult to establish, in adapting the nature of the exterior circuit, including the lamp, to the peculiarities of each machine, that I should not regard these conclusions as absolutely final.

In the Wallace-Farmer machine (Fig. 29) the magnetic field is produced by two horse-shoe electro-magnets, but with poles of opposite character facing each other. Between the arms of the magnets, and passing through the uprights supporting them, is the shaft, carrying at its center the rotating armature.

This consists of a disc of cast iron, near the periphery of which, and at right

angles to either face, are iron cores, wound with insulated wire, thus constituting a double series of coils. These armature coils (Figs. 30 and 31) being connected end to end, the loops so formed are connected in the same manner, and to a commutator of the same construction as that of the Gramme. As the armature rotates, the cores pass between the opposed north and south poles of the field magnets, and the current generated depends on the change of polarity of the cores. It will be seen that this constitutes a double machine, each series of coils, with its commutator, being capable of use quite independently of the other; but in practice the electrical connections are so made that the currents generated in the two series of armature coils pass through the field-magnet coils, and are joined in one external circuit. This form of armature also presents considerable uncovered surface of iron to the cooling effect of the air, but its external form, in its fan-like action on the air, like that of the Brush, presents considerable resistance to rotation. In the Wallace-Farmer machine there was considerable heating of the armature, the temperature being sufficiently high to melt sealing wax.

Another machine made and used in this country to a considerable extent is that of Mr. Brush, manufactured by the Telegraph Supply Company, Cleveland, Ohio. This is shown in Fig. 32.

The Brush machine has for its magnetic field two horseshoe electro-magnets,

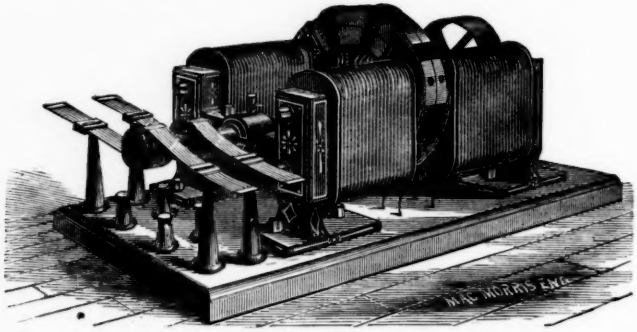


Fig. 32.

with their like poles facing each other, at a suitable distance apart, the circular armature rotating between them.

In this machine the currents are generated in coils of copper wire wound upon an iron ring, constituting the armature. This ring is not entirely covered by the coils, as in the Gramme armature, but the alternate uncovered spaces between the coils is almost completely filled by iron extensions from the ring, thus exposing large surfaces of the armature ring for the dissipation of heat, due to its constantly changing magnetism, as in the Pacinotti machine.

The ring revolves between the poles of two large field magnets, the two positive poles of which are at the same extremity of the diameter of the armature, and the two negative poles at the opposite extremity, each pair constituting practically extended poles of opposite character.

The coils on the armature ring are eight in number, opposite ones being connected end to end, and the terminals carried out to the commutator. Figs. 33 and 34 show this arrangement, only one pair of coils, however, being shown in Fig. 33 as connected. In order to place the commutator in a convenient position, the terminal wires are carried through the centre of the shaft to a point outside the bearings.

The commutators are so arranged that at any instant three pairs of coils are interposed in the circuit of the machine, working, as it were, in multiple arc, the remaing pair being cut out at the neutral point; while in the Gramme machine, the numerous armature coils being connected end to end throughout, and connections

being made to the metal strips composing the commutator, two sets of coils in multiple arc are at one time interposed in the circuit, each set constituting one-half of the coils on the armature.

The commutator consists of segments of brass, secured to a ring of non-conducting material, carried on the shaft. These segments are divided into two thicknesses, the inner being permanently secured to the non-conducting material, and the outer ones, which take all the wear,

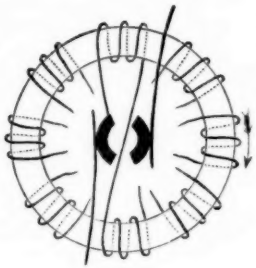


Fig. 33.

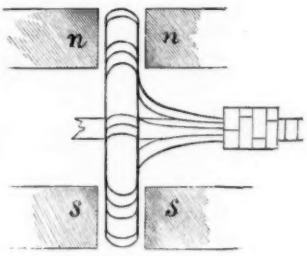


Fig. 34.

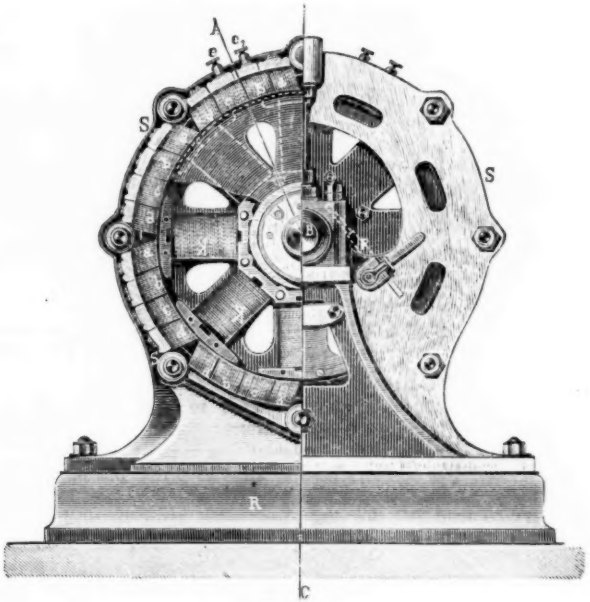


Fig. 35.

are fastened to the inner in such a manner that they can be easily removed when required.

The commutator brushes, which are composed of strips of hard brass, joined together at their outer ends, are inexpensive and easily renewed. The high speed at which these machines are run, together with the form of the armature, causes the rotation of the latter to be considerably resisted by the air, and producing a humming sound, but otherwise

they run smoothly, the heating of the armature being inconsiderable—not exceeding 120° Fahr. after four and three-quarter hours' run.

Another dynamo-electric machine which has been operated with much success in many places is that of Mr. Hiram S. Maxim, of New York.

In general construction it much resembles the Siemens machine as to its field magnets and the Gramme machine as to is armature, though there are differences more or less important in both. The armature is like the Gramme in consisting of a series of coils arranged into an annulus, but this annulus is length ened until it becomes a drum or cylinder. In place of an iron-wire core, this ring or drum of coils has a series of thin iron rings, so cut from sheet-iron as to escape having any fiber in the direction of their circumference.

Two of these machines have been thoroughly tested in the course of the experiments herewith to be reported, and have shown themselves to be very efficient.

When the Jablochkoff candle came into vogue it became highly important to go back in one of the directions in which

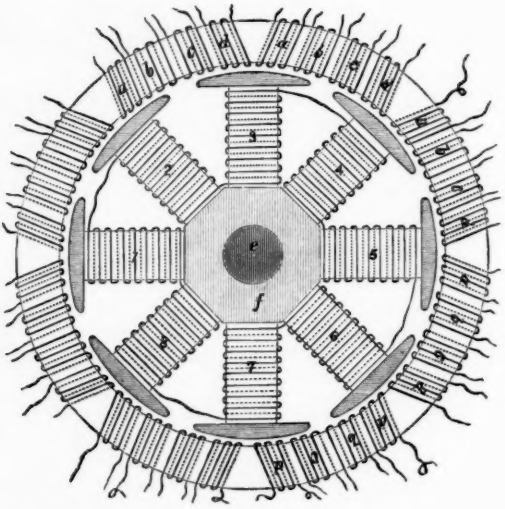


Fig. 36.

improvement had been made in most of the recent machines, and produce a machine which should yield alternating or reversing currents, in place of those passing continuously in one direction. This was necessary to equalize the consumption of the two parallel carbons of the Jablochkoff, and also even with other lamps, for purposes which we will explain further on.

To meet this requirement Gramme has arranged a machine which not only produces alternating currents, but operates readily, at the same time, a number of separate circuits. It is these machines which were recently used during the exposition to light certain streets and public places in Paris. The general appearance of this machine is shown in Fig. 35. readily understood from the diagram Fig. (36).

This machine, it will be observed, differs radically from the continuous-current machine of Gramme.

In the first place, it is, as it were, turned inside out. Thus there is a magnetic ring wound with successive coils, but this, in place of revolving within the field of fixed electro-magnets, is stationary on the outside, while a series of eight electro-magnets, excited by a separate machine, rotate in the interior of this fixed armature ring.

The principle of the machine will be

The interior system of electro-magnets is so wound that the polarity of each spoke is reverse to its neighbors. These magnets, therefore, by induction develop eight consecutive poles in the soft iron of the surrounding ring, and, as they revolve, the poles of this ring move with them. Thus, while in the older Gramme machine the actually moving ring had poles stationary in space, over which the coils passed, in this case the actually stationary ring has moving poles which pass through the stationary coils.

These coils are wound in eight sets, each alternate set being wound in an opposite direction, and each set is made up of several separate coils, to facilitate the making of all sorts of combinations, which are most easily arranged in this machine, as no commutators are used, and all the coils are fixed.

If all the coils marked *a* are connected together, it is evident that at any moment the currents in all of them will be in the same direction. Thus, suppose the electro-magnet spoke 2 to have a north pole at its outer end, and 3 to have a south pole similarly situated; then as 2 moves over *a* it will produce a current alike in direction to that produced by the opposite pole of 3 moving over the oppositely wound wire of the next coil marked *a*.

Of course, as the magnet 2 leaves *a* and the oppositely polarized magnet 1 approaches, this current will be reversed in the first coil marked *a*, and also likewise in the second coil *a*, for a like reason.

It has been stated that these machines worked one Jablochkoff candle for each horse-power consumed, but several who watched their actual running say that very much more power was actually consumed.

PICTET'S PROPOSAL TO DISSOCIATE THE METALLOID ELEMENTS.

From "Nature."

DURING the last two years M. Pictet has published several important memoirs upon different branches of thermo-dynamics, and has, as is well known, in his researches on the liquefaction of oxygen and of hydrogen shown the fruitfulness of the ideas which have thus occupied him. He is at the present moment engaged upon a large volume entitled *Synthèse de la Chaleur*, a work in which it is sought to deduce all the known laws of heat from the general principles of theoretical mechanics, by finding true mathematical definitions for the quantities which hitherto have been usually expressed as simple experimental matters. Thus the terms "temperature," "specific heat," "latent heat," &c., are capaple of exact definition in a manner which enables the relations between them to be investigated analytically. These relations thus investigated are found by M. Pictet to be capable of experimental verification, and the complete accordance of deduced theory with observed fact justifies him in giving the name of *Synthesis of Heat* to this new advance in thermo-dynamics.

To understand aright the views of M. Pictet, with respect to the possible dissociation of the metalloids, we must notice briefly the fundamental points of his theory of heat. If the atoms of a body are in absolute rest and equilibrium, their temperature will be at *absolute zero*. If, however, kinetic energy is imparted to these atoms and they are set vibrating, the *temperature* of the body will be represented by the *mean amplitude* of the oscillations, and the total *quantity of heat* in the body will be the quantity of energy thus imparted.

Now the great decomposing force in nature is heat. It is heat which changes solids to liquids, liquids to vapors. Heat breaks up chemically combined substances and reduces them to simpler forms. It is quite certain that the limits of the power of the chemist to decompose the substances that pass through his hands are those which correspond to the temperatures which he can produce in his laboratory. We shall explain at a later portion of this article how this comes to be the case. Yet there are in

nature temperatures far more elevated than the highest artificial temperature. To take the most striking example, the surface of the sun must be enormously hotter than even the hottest of the electric arcs in which even the most infusible of metals is vaporised. We know this upon evidence which acumulates every day, and of which the most important is that afforded by the spectroscope. The researches of Kirchhoff and J. W. Draper, and the later work of Cornu, Mascart, and Lockyer, establish incontestably that the radiation emitted by a glowing substance varies with the temperature of the substance, and that at higher temperatures new rays of shorter wavelength and more rapid oscillation appear, while the intensity of all the emitted rays is also greater. The solar spectrum is much more rich in violet and ultra-violet rays at the more refrangible end of the scale than the spectrum of any artificially heated substance. The irresistible conclusion is that its temperature is far higher.

But the spectrum of the sun when scrutinized with the most elaborate skill and knowledge reveals another very striking circumstance. A large number of the substances regarded by the chemist as *elements* have now been recognized by the characteristic absorption lines of their spectra as existing in the heated matters surrounding the sun. The researches of Mr. Lockyer show that nearly forty of the metals are thus to be detected. But *not a single metalloid* is thus discoverable. Indeed so marked is their absence that the presence of hydrogen in such great abundance is held by no less an authority than Mr. Dumas to be a convincing proof that hydrogen is a metal and not a metalloid. It is true that Mr. Henry Draper of New York, has announced the discovery of *bright* lines corresponding to oxygen amongst the dark absorption lines of the solar spectrum; but it is far from certain whether the coincidence he has pointed out is real or apparent only, and all other evidence points to an adverse conclusion.

Putting together these two capital facts of solar spectroscopy, the irresistible inference is that the surface of the sun is too hot for metalloids to exist there; or in other words, *its temperature is higher than the temperature of the dissociation-points of the metalloids.* This term dissociation-point is justified by analogy with the terms boiling-point and melting-point, with which we are familiar, and with which we associate the notion of definite temperatures.

Let us examine, following M. Pictet's fundamental principles, how far this analogy can be followed out and justified. Those fundamental principles are that in hot bodies the molecules are swinging to and fro about positions of equilibrium; that "heat" *is* the energy of these molecular vibrations; and that the "temperature" of the body *is* the mean amplitude of the vibrations. If more energy is imparted to a solid, the more energetically will its particles oscillate, the longer will be the mean amplitude of their oscillations, and the higher the temperature. If we allow that the gravitation law of attraction, namely that the attraction between two masses varies inversely as the square of the distance between them, holds good not only on the grandest scale but also on the most minute, we must admit that the force acting on a vibrating particle at the furthest limits of its swing, and tending to attract it back, will be relatively weak as the amplitude of the swing is great. Hence too long a vibration may carry the particle right beyond the field of molecular attraction; and the particle will not return but will carry off with it in the form of potential energy part of the heat furnished to the body. The sum of these small quantities of potential energy which must necessarily disappear from the body during its change of state from the solid to the liquid condition constitute that which we usually term "latent heat."

Now consider a solid body at the absolute zero of temperature to which new quantities of heat are continuously imparted. What will be the successive changes to be observed? At first the temperature of the body will rise proportionately to the quantity of heat imparted to it. When the vibrations of the particles have attained a certain amplitude, fusion will take place, not all at once but gradually, each molecule passing away from the attraction of its neighbors, as soon as its vibration is

sufficiently energetic. Each solid particle will thus be split up into two or more liquid molecules exactly resembling each other. Every one of these molecules will require potential energy, hence during the entire process of liquefaction, the whole of the heat imparted will be employed in producing the change of state; so that the temperature will be stationary in spite of the continual addition of heat. But when the whole substance has melted, the temperature will again rise up to a certain point determined by the commencement of ebullition, a point which will vary with the conditions of external pressure. This second change of state arises from a further splitting up of the molecules into two or more portions each, every separated portion again carrying off with it a further quantity of potential energy, the "latent heat" of vaporization. If the gaseous molecules thus produced receive still further quantities of heat, the temperature will go on rising until another point is reached, corresponding to a first chemical *dissociation*, when, as the lengths of oscillations become excessive, the separate atoms are successively thrown apart. This process, like those of liquefaction and vaporization, will be accompanied by the absorption of heat. The extent to which energy must be furnished in order thus to produce chemical separation, will be proportional to the chemical affinity of the separated atoms; and if the body consists of several chemical constituents it is probable that some of these will be dissociated at lower temperatures and some at higher. The limits of dissociation will have been reached when the body has been separated into its ultimate particles or true elements.

The striking feature of this series of changes is—that while the addition of quantities of heat goes on continuously the rise of temperature is discontinuous, having several stationary points in the range between the absolute zero and the highest possible temperature; each fresh stationary point corresponding to a change of state, or a decomposition of the particles into simpler forms.

Suppose next that we could reverse the order of operations, and could abstract the heat continuously from the dissociated bodies, we might expect to find the same series of changes occurring in the inverse order. But this expectation would not be realized, for reasons which are not difficult to find. In the two changes of state which are of a nature usually termed *physical changes*, namely liquefaction and vaporization, the result of the splitting up is to produce particles all of the same kind. In a liquid — water, for example — all the liquid particles are water. In a vapor —steam, for example—the particles are all particles of steam. But in the case of *dissociation*, which is a *chemical* change of state, the result of the splitting up is to produce particles not all of the same kind. Thus, if steam is passed through a white hot platinum tube, the dissociated matters are of two kinds, oxygen particles and hydrogen particles. In the changes denominated "physical" which produce homogeneous particles, the recombination does not depend on the relative *positions* of the constituents but only on *pressure* and *temperature*. In the changes denominated "chemical" which, as we have seen, produce heterogeneous particles, the recombination of the constituents depends on their relative *positions* and on the way in which they have to be grouped in the compound, as well as on pressure and temperature. This most important distinction must not be overlooked.

Again, the dissociated chemical atoms carry away with them in a potential form the heat which has disappeared during the process of dissociation, exactly as a liquid carries in a potential form the "latent heat" which disappeared during the process of liquefaction. If we collect the separated chemical constituents—the oxygen and hydrogen for example—and make them recombine, they will evolve this potential energy and the heat will reappear. The limit of temperature, therefore, which can possibly be reached by the combustion or chemical combination of any bodies is precisely the temperature of the dissociation point of the substances formed. Hence there is obviously, as we remarked at the outset, a limit to the power of the chemist to dissociate bodies; a limit determined simply by the temperatures he can artificially produce.

It will be remarked, however, that we have in the electric current a means of

obtaining many decompositions which without its aid would have been unknown to us. We may even assert upon the certain evidence of the spectroscope that the temperatures attained by the electric spark are far higher than those of any known combustion. Nevertheless there are here also limits which cannot be passed. If in the circuit of the most powerful battery we interpose a conductor of considerable resistance its temperature will rise; and if the conductor be reduced in thickness to augment its resistance, will continue to rise until the conductor itself is either liquefied, volatilized or dissociated, when of necessity a practical limit is reached in the entire stoppage of the current. Again, with the discharges from induction coils and Leyden jars, which take place even across gases, there must be a limit, determined by the absorption of energy by the very molecules which are concerned in the discharge, and whose resistance to the electrical action will increase with their temperature. It is a point which may admit of some further discussion. But, on the whole, one is led to the conclusion that the dissociations we have shown to be theoretically possible are in a very large number of cases absolutely beyond the practical limits of experimental achievement.

One course yet remains open. We have not hitherto considered the connection between temperature and radiation in its bearings upon this question. It appears that every temperature, as defined above, corresponds to a definite kind of radiation. Every calorific oscillation of a particular rate is then associated with the propagation of a wave of disturbance in the surrounding ether; this wave having a particular frequency, or, what is the same thing, a particular wave-length. When these calorific waves in passing through space meet a body they tend to set its particles vibrating; and, what is more important, tend to set them vibrating in unison with the original vibrations of the radiating source. If it were not that the receiving body were subjected to external influences, it would acquire little by little exactly the same temperature as the body from which the radiations were emitted. In other words, thermic equilibrium would be established between the two, quite irrespective of the distance between them. We know that the rays of the sun traverse space without any diminution in their frequency or wave-length. It follows, therefore, *that the sun's rays are able to raise to a temperature equal to that of the sun's surface any body on the surface of the earth on which they can be concentrated*, provided only such a body could be preserved from losing heat by conduction or radiation. Although a certain quantity of the solar radiation is arrested by absorption in the imperfectly transparent atmosphere surrounding the earth, measurements made at places so widely apart as Cairo, Paris, and St. Petersburg agree in showing almost identical values for the amount of heat received from the sun, and which is about twelve calories, per square meter, per minute.

Now on the supposition that all the metalloids, with the exception, perhaps, of oxygen, are dissociated in the sun, thermal equilibrium, if thus experimentally obtained, ought to affect the dissociation of them upon our globe also.

M. Pictet therefore proposes that an enormous parabolic mirror should be constructed, in the focus of which the sun's rays should be concentrated upon the various metalloids which it is sought to decompose. All the data for calculating the requisite size of the mirror are known to a certain approximative value, with one exception. We know the quantitative intensity of solar radiation, and the reflecting power of polished metals, and hence can calculate how many units of heat a mirror of given size will hurl into its focus per minute. *We do not know* how much heat must be furnished to a given weight of any one of the hitherto undecomposed metalloids to dissociate it, but we are quite certain that this quantity must be much greater than that produced by the combustion of an equal weight of hydrogen and oxygen. Assuming that to dissociate bromine required *a hundred times* as much heat (at the temperature of its dissociation-point) as water vapor requires (at *its* dissociation-point) to split it up, M. Pictet calculates that a single gramme of bromine must have 350 calories expended upon it to resolve it into its elements. Further calculation leads him to consider that to dissociate one

gramme of bromine per minute, would require that the solar rays should be concentrated by a mirror of *at least* 35 square meters of surface, measured normally to the rays, or of about ten meters' aperture. It would, he thinks, be best constructed in separate pieces of about a square meter in area, each ground and polished to a true curve and mounted in a special frame. The depth of the mirror should be equal to half its aperture, bringing the focus into the plane of the rim. At the focus would be a special *solar chamber*, or crucible, constructed of lime or zircon, or other refractory substance, into which the vapors to be operated upon would be led. To avoid loss of heat it would be kept hot from without by oxyhydrogen flames. The whole apparatus ought not, he thinks, to weigh as much as two tons. To catch and retain the dissociated substances, and to prevent their immediate recombination, he proposes to aspirate the vapors of the chamber through metal tubes containing metallic gauze, and cooled from without to a temperature perhaps as low as 50° by intense artificial refrigeration. The rapid cooling thus produced should hinder at least a considerable proportion of the constituents from recombining as fast as they were liberated from each other in the solar chamber.

There is much that is suggestive in the proposals of M. Pictet; so much, indeed, that any attempt at criticism or comment would outrun the limits of this article, which is therefore simply devoted to the exposition of M. Pictet's ideas in phrases as nearly identical as possible with those in which he has himself expressed them.

ON THE STRENGTH OF IRON AND STEEL UNDER MOVING LOADS.

By H. LIPPOLD.

From "Organ für die Fortschritte des Eisenbahnwesens."
From the "Abstracts," translated for the Institution of Civil Engineers.

THE author begins by quoting a general law, derived by Wöhler fron his experiments on railway axles: "A material may be broken by repeated oscillations of load, no one of which produces a strain equal to the breaking strain. It is then the differences between the alternate strains in opposite directions which destroy the cohesion of the material, and the absolute intensity of the strain has only an influence so far that the higher this intensity the smaller are the differences which are sufficient to produce rupture."

Wöhler's experiments were made, first with actual axles, and afterwards with bars about five inches square, revolving under heavy loads. The highest speed was, however, one revolution per second, whereas the wheel of a train at thirty-five miles per hour makes about five revolutions per second. Consequently his results compare better with the cross girders of a railway bridge, which are suddenly put under strain by the advance of a train; but they differ from these inasmuch as in the latter case the strain, once put on, is maintained until the whole train has passed, *i. e.*, for several seconds. This longer duration of strain has a great effect in causing rupture, as is shown by two sets of experiments of Wöhler's, in one of which there were four oscillations during each revolution of the bar, and in the other case one oscillation only, the strain being kept on for three-quarters of each revolution. In the former case the iron withstood 732,572 oscillations, as against 170,900 in the latter. The reason of this fact, doubtless, is that the permanent set, and even the temporary deformation of the material, requires a certain time for full development. It is very desirable that further experiments should be made on this point.

The influence of the speed of the moving load is next considered. The effect of this on the deflection appears to be very slight. In a report on the test-

ing of Prussian railway bridges (1862) it is stated that the greater or less speed of passing trains, up to forty-five miles an hour, produced no sensible variation in deflection in most cases, and never more than a very slight one. It does not follow, however, as Wöhler supposes, that the effect of speed may be neglected. Suppose a train to advance on a bridge very slowly, then the material at the center is only brought very slowly to its maximum stress; consequently it has ample time to take up the strain or deformation corresponding to that stress, and no oscillations follow. But suppose the train to advance rapidly; then the maximum stress comes on rapidly, and produces oscillations about the point of the maximum strain, the effects of which are more severe as the velocity increases. The reason why this does not appear in the total deflection is that the time of oscillation of any one piece varies as the square root of its length; hence, as the pieces of which the bridge is composed are of various lengths, their oscillations interfere with each other, and the total deflection may thus be even less than with a stationary load, as has been actually observed in at least one experiment. In riveted bridges, the deformations caused by the rigidity of the joints also come in to complicate the result. The dynamical effect of the moving load must, therefore, be taken into consideration, and this can only be done by assuming the worst possible case, viz: where the train comes on instantaneously. For this purpose Wöhler's principle is re-stated as follows: For the breaking of a piece a certain quantity of work is necessary; and this work may be done upon it either at once or by repeated applications of loads, provided that the latter succeed each other so rapidly as to produce oscillations.

The testing of a bar of iron or steel, by slowly applied loads increasing up to rupture, is known to fall into three periods. In the first, the elastic extension is proportional to the load, and the permanent set so small as to be neglected. The limiting load of this period the Author calls the original limit of elasticity. In the second period, the elastic extension is proportional to the load, but the permanent set increases in a higher proportion. In the third, the permanent set increases much more rapidly, but the elastic extension remains proportional to the load up to rupture itself. The increase of set is partly due to the contraction of the bar in the immediate neighborhood of the point of ultimate rupture. The amount of this contraction depends on the section; and hence the permanent sets in this third period are not proportional to the length of the bar. If, in the second period, the same load is again applied, the Author considers (on what ground he does not state) that no increase of permanent set takes place; consequently, the elastic extension is the only extension which occurs, and thus, practically, the limit of elasticity has been raised so much beyond its original limit. The whole process is represented graphically by a curve, of which the ordinates are loads, and the abscissæ extensions. The area of this curve, measured up to any ordinate, represents the work done by the corresponding load. But it is known that a load applied suddenly will produce the same extension as double that load applied gradually. Hence, within the limit of elasticity, a suddenly-applied load will do the same work as double that load applied gradually; and by what has been said the limit of elasticity may be raised to any point short of rupture by repeated applications. Hence it follows that repeated and sudden applications of a load cannot produce rupture, unless it exceeds half the breaking load; also, that the final result of such a load is to produce the same effect as a gradually applied load of double the amount. These conclusions are confirmed by Wohler's experiments on steel, where the lowest stress which produced rupture by sudden repetitions was almost exactly half the absolute breaking stress. With iron this is not the case, as the value of the absolute breaking stress appears to be raised by the repeated loading. In a similar manner, when a piece is already loaded with a strain P, may be found the greatest additional load which can be suddenly and repeatedly applied without causing rupture. It appears that this equals $\frac{P+B}{2}$, where B is the absolute breaking stress. The examination of a particular example from Knut Styffe's work confirms these general conclusions. A table annexed gives,

in addition to the strains and extensions, the work done in bringing on the strain slowly, and so producing the extension; and also the suddenly applied load which would produce the same result. An examination of this table clearly shows the diminished effect of the sudden load, in cases where it is not given time to produce its full extension; the remainder of the work is of course converted into heat, which might easily be registered in future experiments by the use of the thermo electric pile. The table further gives for each state of strain the additional sudden load which would at once produce fracture, and the greatest additional sudden load which would fail to produce fracture, even when repeated any number of times.

All circumstances of strain which cannot be reduced to actual calculation must be allowed for by the factor of safety. These, which continually diminish in number as science progresses, are mainly the following: the influence of rigid joints in riveted bridges; the shocks arising from inequalities in the permanent way, or in the movement of the vehicles; and the defects in construction, or differences of strength in the materials employed. They may be brought to a minimum by various practical regulations. From an example it is deduced that the influence of the unknown stresses arising from shocks may be as great as that of the moving load, and that they may be allowed for by taking the ultimate strength of the structure, or the limit of elasticity, at $\frac{7}{10}$ of its real value. The unequal stresses arising from rigid joints are more troublesome, as it is quite impossible to examine their nature. On the whole, however, it will suffice to lay down the principle that a structure must never be loaded with a stress greater than $\frac{7}{10}$ of its limit of elasticity.

These general principles are applied to the case of the working live loads of permanent structures, and formulæ are deduced from them. From these and from experiments it would appear that when alternate tensile and compressive strains are rapidly brought upon a structure, the ultimate strength is not much affected in the case of iron, but is decidedly reduced in the case of steel. In view of the increasing use of the latter material, this result seems to demand further investigation.

HISTORICAL BRIDGES.

From "The Building News."

The recent disaster on the Tay recalls to mind some memorable associations connected with the history of bridges. Our examples, however, will be taken from periods long anterior to that of what has been described, whether inaptly or not, "wirework architecture." The literature of the subject is superabounding, from the days of Vitruvius to those of Vignolles. The motto of the ancient Romans was—First, a highway, next, a bridge. Without it, armies were checked in their advantage; commerce was impeded; social intercourse became almost impossible. The same truth has held good in all ages; from the scheme of Darius, designed for the invasion of Thrace, across the Bosphorus; the famous structure thrown over the Danube by the Servians of the fourteenth century, to assist in the defence of Nicopolis, and those which were projected by Pyrrhus across the Adriatic, by Caligula across the Tyrrhene Sea, and by Cæsar across the Rhine. Many a tradition has come down to us concerning the bridges over the Tiber, the Ælian, and those of the Holy Angel; of the Consuls, and of the Lady, with its "symphony" arches; and their ancient chronicles, in respect of calamity and destruction, are much in accord with those of others, more modern in type, at Avignon, Ay, Bordeaux, Luzon, St. Esprit and Aveyron—with its eighteen arches, once partially wrecked by such a storm as lately swept the Tay. Similar vicissitudes have occurred in France to the "Royal Bridge," of the Tuileries; to that of Lyons, which, like the other at Aveyron, had eighteen arches; to that of Toulouse, across the wide and swift Garonne; to the Farnese,

at Parma, and to many besides, which have left their relics along the Flaminian Way. Next to the temples and palaces of a country, its history has, perhaps, been most truly told by the ruin, or the neglect, of its bridges. They bespeak, moreover, something characteristic of the Government, and the manners that once held sway. Those of Rimini were approached through marble porticoes. Those on the road from Trent to Bassano, carried over stupendous gorges, from one giddy height to another, told of sudden flights, and the breaking down of an enemy's means of passage. In a modern epoch, Arcola and Lodi were the centers of tremendous battles, and in all strategy the "head of the bridge" has been regarded as a vital point. It is worthy of remark, moreover, from a different point of view, that among all the three hundred and fifty-nine older bridges of Venice, not one has ever been permitted to fall into decay. And yet, they were only built for foot-passengers, in a city where wheeled vehicular traffic was practically unknown. Those of Amsterdam and Rotterdam scarcely belong to the category. The historical structures now referred to differed, of course, in many repects, though not in all, from those with which the modern and popular mind is familiar. They had nothing in common with the fabric that lately spanned the Tay, with the Menai, or its Tubular neighbor. There was no Niagara for the ancients to bridge; but Trajan had to rear his arches a hundred and fifty feet above the flow of the Danube, and to give them an ample breadth simultaneously. But that which Trajan raised his successor leveled. "A bridge," said the one, "is the means of promoting intercourse and commerce." "A bridge," said the other, "is an invitation to an invader." But the foundation piles, to this hour, remain; and every now and then, are drawn up from the bed of the river. It is, perhaps, hardly reasonable to include, among edifices of this class, that of Xerxes, on the Hellespont, only temporary in its character and purpose, any more than that which was reported to have been thrown by Alexander across the Ganges; but it will be well for modern Europe, if it can present, after a similar lapse of time, such an illustration as the Ælian Bridge, built by Hadrian, and now known as the Bridge of the Holy Angel, at Rome. We have had examples of apparent indestructibility in England; and certainly, those of the Thames, from Westminster downwards, would seem to challenge the efforts of both tide and time. Westminster itself, Waterloo, Blackfriars, and London, suggest, in their several ways, the idea of architectural immortality; but it is to remembered that the Roman works of this class were not all equally durable. Thus, the "Triumphal Bridge" of the Cæsars, still encumbers the Tiber with its fragments, though the Janiculan stands steadfast, while the Ostine has survived to be re-named the bridge of St. Bartholomew. So, the classic Tarpeian is now the Caspi; the Senator's, on the Palatine, was christened the Holy Maria; the Horatian, one of the most beautiful in Rome, and of which only a few scarcely-distinguishable relics remain, would have been re-named, had not a second structure been erected above the first, more like a portico, or a triumphal arch, than a bridge, so aspiring were its proportions, and the bound of its central arch. The bridges of Avignon—long ago a ruin—of Lyon, on the Rhone, and of St. Esprit, were all designed in imitation of these.

Among Italian historical bridges, that constructed by Alexander Farnese, Duke of Parma, was, perhaps, the most architectural, nothing of this character being claimed by the celebrated one "of sighs" at Venice. Palladio, in his day and generation, was great in the design of these structures, as witness that of Rimini already mentioned, on the Flaminian Way; that of Vicenza, on the river Bachiliogni, and that of Verona. But his grandest conceptions were never carried out. One among them represented a bridge which should be composed of several streets, along which no vehicle should ever be allowed to pass, of lodges, porticoes, and statues of marble and bronze. At Madrid there is an edifice—that of the Marzanani—which may almost be described as at once a bridge and a gate, while in the little town of Munster, on the Navante, was formerly constructed a bridge of a single arch, far surpassing in boldness that of the Rialto, at Venice, though this latter has often been eulogized as a mas-

terpiece of Michael Angelo's genius. Palladio bore in mind, as a bridge architect, the necessities which have to be encountered in different regions; ice and long winters in one, snow-meltings and floods in another, tempests of wind in a third; and he has made use of the most accurate calculations available in his time of the conditions represented by the Royal Bridge on the Seine, at Paris, that across the Tiber at Rome, that across the Rhone at Lyons, that across the Garonne at Toulouse, and that across the Thames in London. Those flung over the Tiber have had to withstand, excluding the current century, no fewer than thirty overwhelming inundations and swellings of the river, and it is certainly a remarkable circumstance that any one of them should have been left with one stone standing upon another. The Bridge of Caersau, in Languedoc, though constructed, as its builders thought, exactly on the Roman plan, gave way to the first assault, and even the enormous piles upon which it was reared were rooted out of the depths to which they had been driven. The Emperor Trajan, in building his bridge over the Tiber, would not trust to the bed—artificial or natural, whichever it might have been—of the stream, but excavated another and thence commenced his constructive operations, and the renowned Blendel, at Xaintes, on the Clarente, stipulated for a deep foundation of concrete, as concrete, was understood in those days, before he would put a cubic yard of either timber or masonry into his work. Many of these ideas, no doubt, were not less crude than they were old-fashioned, yet they exemplify how the science and practice of bridge-building have grown up in various parts of the civilized world, and the uncivilized also, since long before a suspension bridge was thought of in Europe, it had been a familiar principle among the wildest tribes inhabiting the jungles of Asia, who found in the flexible and elastic bamboo the materials of such edifices ready to their hands, and who elaborated them with a marvellous instinct as to weight, balance and capacity for resisting the variable temper of the weather and the attacks of floods. It is true that no human precaution can always suffice to prevent danger to such, or similar edifices, from hidden causes. Michael Angelo Buonarotti himself, though he laid the foundations of St. Peter's, at Rome, with every conceivable precaution, did not reckon upon the subterranean percolations down from the summit of the Vatican and Janiculan hills. The great Corderic of Rochefort, also, was thus undermined, and so with the foundations of many ancient bridges; there were rivers under rivers, streams under streams, never taken into account by the architect, yet, nevertheless, fatal, in the long run, to his work. There was a long controversy, at one time, concerning the materials to be employed, stone, marble or timber. Timber, clearly, would not suffice for enterprises of the first magnitude, constituting the prolongations or junctions of imperial highways. The Romans and the Gauls, as a rule, pronounced in favor of the hardest stone, rising above buried forests of oak or pine, while the Italians, generally speaking, declared for marble, at once their favorite and their most familiar product. "A bridge," said Michael Angelo, "ought to be built as though it were intended to be a cathedral; with the same care, of the same materials;" and he only repeated the words used by the unknown architect, a Roman, of the apparently imperishable Pont du Gard, in which the mason and the mathematician would seem to have had an equal share. The bridge of La Guillotiere, on the Rhone, was built on precisely the same system, and is a ruin; but it was not destroyed by time or ordinary wear and tear, it was blown up in time of war; and to its architect was attributed the blame properly due to a company of French sappers and miners, with whom, as they themselves say, "nothing is sacred"—nor to their architects either, in another sense, because there was once a project for bridging the Nile, a river which never yet has known a bridge, in the proper sense of the term. The French, however, during their occupation, conceived the idea, ransacked the entire valley for stone, cast predatory eyes upon the pyramids, and were only deterred from their undertaking, one never dreamed of, even by the most magnificent of the Pharoahs, by the exigencies of war. Had they not discovered a sufficiency of stone, their engineers, it was announced, would fall back upon the bricks, in the supply of

which Egypt has never failed. Why not? it was asked. The beautiful structure at Toulouse was originally brick-built from base to parapet, though its elaboration approached that of sculpture. Among other edifices of this class, however, must not be forgotten those which were expressly designed to break the force of torrents and descending masses of ice—solid, yet complicated, arrangements, all traces of which were long ago swept away, but which once were famous in the valleys of the Alps and Pyrenées. In point of fact, since bridges have, in all civilized times, been found essential to the mutual intercourse of populations separated by rivers, it is not surprising that they have equally, in all civilized and artistic times, engaged the utmost ingenuity of mankind, in order that they might be, if possible, at once safe, splendid and commodious.

SOME DIFFICULTIES ENCOUNTERED IN SINKING A SHAFT FOR THE SECOND LAKE TUNNEL AT CHICAGO, ILL.*

By Mr. ELIOT C. CLARKE.

This shaft was sunk in the well of the water-works crib in Lake Michigan, two miles from shore. The writer was assistant engineer in immediate charge of the work, which was carried on in 1873.

One shaft connecting with a five-feet diameter tunnel had previously been built in the crib well, and the new shaft was to be used in building a second and larger tunnel. The water in the well was about thirty-two feet deep, and the tunnel was to be about thirty-five feet below the bottom of the lake at that point. The shaft consisted of a cast-iron cylinder, and no difficulty was experienced in sinking it through the water, and for about thirty feet in good clay. At that depth a vein of sand was met with, which probably extended to the tunnel previously built. A great deal of water came into the shaft from this sand, and it was feared that even if it was possible to pump it, much sand would run into the shaft with the water, and perhaps, by leaving cavities about the first tunnel, cause it to be broken. It was therefore decided to force the water out by use of the plenum process. Air pumps were procured, an air lock put upon the top of the cylinder, the water driven out by air pressure, and the work proceeded under these conditions.

The speaker then described the difficulties attendant on the use of compressed air, especially the many cases of "caisson disease" from which the workmen suffered. The intensity of pressure varied from thirty to thirty-five pounds per square inch. About twenty-five cases of disease occurred. The symptoms consisted of severe pains in one or more of the limbs, sometimes involving the head and trunk. In more than one half of the cases there was present partial or complete paralysis of the parts affected. Two cases of slight paralysis unaccompanied by pain occurred, one of an arm, the other of the optic nerve, rendering the patient blind for half an hour. In several cases the pain was intermittent, and seemed very much like cramp, contorting the limbs affected. The duration of the disease in its acute form was from eight hours to three days. In the more severe attacks discomfort was experienced for several days longer, and swellings of the limbs were sometimes two or more weeks in subsiding. In two cases pain was felt at intervals for three months after apparent recovery. There was no fatal case, and seldom any medical attendance. Local applications of "pain-killing" liniments sometimes afforded slight temporary alleviation. A return under pressure invariably banished all symptoms of the disease; but except in three instances, these reappeared on coming out of the air lock. The length of shift was two hours, and three such shifts in twenty-four hours constituted a day's work. The rate of pay for workmen who entered the cylinder was finally raised to $1 an hour.

By such methods, the shaft was finally sunk to the required depth, its bottom secured, the air lock removed, and an

*A paper before the Boston Society of Civil Engineers.

effort was made to begin the tunnel. At the first attempt, when a very small opening had been made in the side of the shaft, an irruption of soft clay and water occurred, which filled the shaft in a few minutes, and nearly drowned the engineer, superintendent and two miners who were at work in it. It was then discovered that the compressed air, escaping, as it frequently did, under the bottom edge of the cylinder, and working its way up along its sides, had demoralized the clay and afforded free access to the water of the lake.

A great deal of puddled clay was first put around the shaft, and an attempt was then made to pump it out. When, however, the water had been lowered about sixty feet, a second irruption occurred.

More clay in bags was then put about the shaft, the water gradually lowered by pumping, and through more than one hundred holes drilled in the sides of the cylinder, in every direction, round iron rods, seven feet long, were thrust out into the clay. It was hoped that the bags would catch upon these rods and be held. A very heavy sail-cloth jacket was also fitted around the cylinder, and extending on the surface of the ground as far as possible, was covered and weighted down with clay and stones. The water was finally entirely pumped out of the shaft; but shortly afterwards a third irruption occurred, the bags of clay and the sail-cloth disappeared, and the shaft again filled with water.

The air lock was again put on the cylinder and the water forced out by air pressure. Attempts made by the most skilful miners to start the tunnel, and to confine the air by using tongued and grooved ash poling boards with leaded joints, were unsuccessful. More clay was put around the shaft, and a horizontal slot was cut in the cylinder, through which fan-shaped, forged iron bars, two inches thick and seven feet long, were driven, forming with each other a solid iron roof above where the tunnel was to be. The demoralized clay extended three feet from the shaft, and the iron roof penetrated four feet into solid clay. Under the protection of this roof the tunnel was at last started, and no more difficulties were encountered. Transferring the line from above ground down to the tunnel required great care in this case. The line was obtained from sights two miles distant on the shore, and was transferred from the top of the crib to the bottom of the shaft by plumb-lines one hundred feet long. As the shaft was not vertical the base obtained at its bottom was only four feet long. From this short base the line was carried about fifty feet southward, where an angle of about ninety degrees was turned, and the line prolonged westward to meet the tunnel already begun from the shore. The error in alignment when the headings met was found to be about eighteen inches.

NEW IDEAS ON HYDRAULICS;

CHIEFLY RELATING TO PIPES, CANALS, AND RIVERS, WITH A THEORY OF THE ESTIMATION OF MOLECULAR RESISTANCES.

By P. BOILEAU.

From Abstracts published by the Institution of Civil Engineers.

THE general motion in a stream is first discussed, and the law announced that where filaments have different velocities, the slower moving deviate towards the quicker. Other external motions, such as eddies and induced currents are then discussed. The periodicity of the motion of translation in streams is pointed out. In a stream moving in contact with solid surfaces, there is a region comparatively limited in extent, near the surfaces, where the internal movements are violent. This is termed the troubled zone. The difference of the law of flow in small and large pipes is ascribed to the large proportion of the section occupied by the troubled zone when the pipe is very small.

The author then shows that a stream in uniform regime may be divided into layers, bounded by surfaces traced out by lines parallel to direction of trans-

latory motion, which have curves of equal velocity for directrices. Each layer consists of molecules having the same mean velocity of translation. The resistance to the motion of the stream is shown to be due to the components parallel to the stream of the reactions due to the roughnesses of the sides; to the shearing of the fluid contained in capillary pores of the surface on which the fluid moves; and to the internal movements in the stream. After some discussion of a general theory of these resistances, the author proceeds to examine the law of distribution of velocities in the section of a stream. He first points out that, in many experiments hitherto made, the necessary conditions for obtaining true results have not been fulfilled. Experiments of his own in 1845 showed that the filament of greatest velocity (the principal filament) divides the vertical longitudinal section of the stream into two parts, in which the distribution of velocity is not exactly the same. Below the principal filament a formula of the form $v=A-Bz^2$, where z is the depth from surface, exactly expressed the law of variation of velocity. Results selected from the Mississippi experiments, and from those of Bazin, confirm the law for extremely different cases. A general expression is then found, applicable to all streams, for the position of the principal filament. In vertical sections other than that passing through the principal filament, the filament of greatest velocity is lower than the principal filament. An expression is then found for the distribution of velocities in a horizontal section, and this is compared with the selected experiments.

The flow of water in pipes is then investigated, some of Darcy's experiments being used to test the results. Taking from Darcy the mean velocities U, and the maximum velocities V, the remarkable result is obtained that

$$\gamma=\frac{V-U}{\sqrt{i}}$$

is constant for each pipe, i being the loss of fall per unit length. Darcy's results being insufficient for the purely empirical determination of the law of distribution of velocity in a pipe, the author seeks a rational basis for such a law. This leads to the adoption of the expression

$$\gamma=a+b\mathrm{R}^{\frac{5}{2}},$$

where a and b are constants depending on the roughness of the sides of the pipe. This enables him to obtain the following law for the distribution of velocity:

$$V-v=\frac{7}{4}\gamma\sqrt{i}\left(\frac{y}{R}\right)^{\frac{3}{2}},$$

where V is the maximum velocity, R the radius, and v the velocity at radius y. From this, formulæ for the mean velocity, velocity in contact with sides and discharge are deduced. It is one consequence of the formula above, that the velocity at a radius 0.6887 R is the mean velocity. Darcy had placed the mean velocity at almost exactly the same point.

The law of distribution of velocity in pipes is then compared with that independently found for streams. It is shown that the former is a particular case of the latter.

The external resistances and internal actions which give rise to the variation of velocity in a stream are then examined, and the defectiveness of the old notions of friction on surfaces, on which Prony's formula is based, is pointed out. For the intensity φ of the resistance to the relative motion of two consecutive layers, at radius y, in a pipe of radius R, the value obtained by the author is,

$$\varphi=\frac{32}{441}\delta\frac{R^3}{\gamma^2}\left(\frac{dv}{dy}\right)^2,$$

δ being the density of the liquid. This expression differs in form from those proposed by Navier, Darcy, Boussinesq, and other hydraulicians, not only as to the influence of the diameter, but also in the variable factor for the same pipe. For canals and rivers the corresponding expression is

$$\varphi=\frac{1}{4}\delta\frac{H^4}{\mu^2}\frac{r_1}{z_2}\left(\frac{dv}{dz}\right)^2,$$

where r_1 is hydraulic mean radius of the liquid cylinder considered, z its depth from the surface, H the whole depth of stream, and μ a constant depending on the roughness and form of channel.

It remains next to estimate the intermolecular work which gives rise to the resistance to relative motion of the layers. In streams the molecules are displaced transversely from slower to

quicker parts, their place being taken by other molecules coming from above. The ratio of the intermolecular work to the whole work of gravity on the stream is found to be

$$\frac{\zeta}{i} = 1 - \frac{w}{U},$$

where ζ is the fall expended in overcoming intermolecular resistances, i the whole fall lost; w is the velocity in contact with the sides, and U the mean velocity of the stream.

Deducting the intermolecular work, the remainder of the resistance to the motion of the stream is due to the action of the surfaces bounding it; and this alone is, strictly speaking, friction. The amount of the intermolecular and frictional resistances in Darcy's experiments on smooth and incrusted pipes is then calculated and discussed.

ON THE NEW COPYING PROCESS.

From "Nature."

A VERY elegant process has recently been introduced into this country for copying and multiplying letters and documents. It is known by various names, according to the etymological skill of the makers. One calls it a "hektograph," another less pardonably calls it the "centograph," while yet another, to bridge the gap between ancient Greek and modern English, styles it the "printograph." But whether it is introduced by these names, or the polygraph, the compo-lithograph, or the velocograph, the principle is the same; though the details are slightly varied in each case. A slab of gelatinous material in a shallow tin tray forms the type. The letter is written with a special ink on any kind of paper, and when dry is placed face downwards upon the jelly, and allowed to remain a minute or more. On removal it is found that the greater part of the ink has been left behind on the jelly. It is only necessary to place pieces of paper on the latter, and on their removal they are found to be perfect fac similes of the original copy. The number of copies obtainable varies with the ink, the most potent being aniline violet, such as Poirrier's. With this a hundred copies may be produced. Others, such as Bleu de Lyon, Bismarck brown, or Roseine,* yield forty to fifty. It was with a view to determine the principles which govern this beautiful process, that I made an examination of the subject. The slab consists of gelatin and glycerine, with carbolic or salicylic acid to prevent fungoid growth, and in the "chromograph" a quantity of barium sulphate is added, which gives the slab a white, enamel-like appearance.

If a hot, strong solution of gelatin in water be prepared,† and then a certain quantity of glycerine stirred in, the whole mass will become solid in cooling. This might at first sight appear to be a solution of gelatin in water *and* glycerine; but such is not the case, the gelatin being quite insoluble in glycerine. When the aqueous solution solidifies, the gelatin still retains the water, but the large quantity of glycerine being dispersed through the mass, makes the whole into what ispractically *a very fine gelatin sponge containing glycerine in its pores.*

The moisture-loving nature of the glycerine prevents the "sponge" from getting dry, while the insolubility of the gelatin in the glycerine prevents it becoming liquid. When the copy is placed on the jelly, the glycerine comes out to meet the ink, for which it has an intense liking. All the suitable inks are freely soluble in glycerine. Some, too, contain acetic acid either in the free state or in combination with bases as in rosaniline

*A very potent and easily prepared ink which will yield a hundred copies, may be made by dissolving rosaniline in a cold-saturated solution of oxalic acid. It must be allowed to dry spontaneously.

†4 oz. gelatin dissolved in 6 oz. water, and 20 oz. glycerine, sp. gr. 1.26, previously warmed, stirred in. Any air bubbles in the gelatin are removed before the addition of the glycerine. A cheaper compound which answers equally well, but is rather darker, consists of Scotch glue, 6 oz., water 8 oz., glycerine 20 oz. These quantities make a slab 10×13×¼.

acetate. The acetic acid exerts a solvent action on the gelatin, so that it will be found that after taking off some impressions with an acetic acid ink, as the "multiplex," the jelly will be etched wherever the ink has come into contact with it. As long as any of the ink remains on the jelly, the glycerine will come out of the pores to keep it moist, but when the whole of the ink has been removed the flow of glycerine ceases, and the parts become quite dry. If the ink is not entirely removed by taking a sufficient number of impressions, and the jelly left, after a lapse of twenty-four hours the remaining ink will be absorbed by the jelly. It is necessary, therefore, that the copies should be taken off as soon as possible, so as to avoid the defect caused by the spreading of the ink.

Most of the makers suggest, that directly the slab is done with, the type should be washed off. The hektograph and most others require that the water should be warm, but the finely divided barium sulphate in the chromograph, renders the surface less tenacious, and the impression may be removed with cold water.

Where practicable, it is better in all cases to leave the slab for twenty-four hours, when the old impression will be quite absorbed, and not interfere with a new one.

This gelatin copying process has been received with so much favor by the public, that it shows there is a great want for some rapid means of getting a limited number of copies of letters, &c.; and seeing that any number of colors may be used in the original drawing, Mr. Norman Lockyer has suggested that it would be of much use in laboratories, for the multiplication of original sketches of biological specimens, and even for spectra charts, and so save much of the time spent in making duplicate copies. The gelatin slab cannot be said to be perfect, as it is liable to be affected by atmospheric changes; but, bearing in mind the fact that the whole is simply a sponge filled with a compound capable of liquefying certain inks, it is reasonable to hope and expect that chromography is only the pioneer of a process, which shall possess all its advantages and none of its defects.

REPORTS OF ENGINEERING SOCIETIES.

ENGINEERS' CLUB OF PHILADELPHIA.—This Society held its regular meeting on April 3d, at which Mr. Rudolph Hering, C. E., exhibited the original drawings of the United States Coast Survey map of the Delaware River from Bridesburg to Fort Mifflin; Mr. A. E. Lehman, M. E., presented a lithographic topographical map of the middle section of the South Mountain range, in Pennsylvania; Mr. Howard Murphy, C. E. submitted a well-preserved volume of Robert Fulton's "Treatise on Canals;" Mr. A. R. Roberts, C. E., described a model of a self-adjusting crossing frog, made for the Philadelphia & Reading Railroad Company, noticing the objections to the ordinary frog, and the manner in which they had been overcome; Mr. Arthur W. Sheafer, C. E., exhibited a diagram, prepared by P. W. Sheafer, Esq., of Pottsville, showing the progress of the anthracite coal trade, and the relation of the amount of coal shipped to market to the coal area. For every ton mined three tons are wasted.

AMERICAN SOCIETY OF CIVIL ENGINEERS.—The last two issues of the Transactions are filled with discussion upon the subject of "Inter-oceanic Canal Projects," participated in by Julius W. Adams, Ashbel Welch, Edward P. North, Walton W. Evans, John C. Campbell, Charles A. Sweet, Frederick M. Kelley, and many others.

It may be safely assumed that the January and February numbers present the most concise statement of this great question that has yet appeared in print.

Paper No. 189, in the March number, contains:—The Engineering Problems involved in the proposed improvement of the Erie Canal by increasing the depth one foot, by E. Sweet, Jr.

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.—The meeting for the organization of this Society was held at the Stevens Institute on the 7th of April. The following rules were recommended at the preliminary meeting:

MEMBERSHIP.

ART. 2. The Society shall consist of members, honorary members, associates and juniors.

ART. 3. Members and honorary members shall be professional Mechanical, Civil, Military and Mining Engineers and Architects.

ART. 4. To be eligible as a *member*, the candidate must have been in the practice of his profession for at least seven years, not merely as a skillful workman, but as qualified to design and execute engineering work, and he must have been in responsible charge of work in his branch of engineering.

ART. 5. *Honorary members*, not exceeding twenty-five in number, may be elected. They must be persons of acknowledged professional eminence, who have virtually retired from practice.

ART. 6. To be eligible as an *associate*, the candidate must have such a scientific or commercial connection with applied science, as will

qualify him to co-operate with engineers in the advancement of professional knowledge.

ART. 7. To be eligible as a *junior*, the candidate must have been in the practice of engineering for at least two years, or he must be a graduate of an engineering school. [The term "junior" applies to the professional experience, and not to the age of the candidate. Juniors may become eligible to membership.]

ART. 8. All members and associates shall be equally entitled to the privileges of membership, provided that honorary members who are not also members or associates, and juniors, shall not be entitled to vote, nor to be members of the Council.

FEES AND DUES.

ART. 18. The initiation fee of members and associates shall be $15, and their annual dues shall be $10 per year, payable in advance at the annual meeting, *provided* that persons elected at the meeting following the annual meeting shall pay $8, and persons elected at the meeting preceding the annual meeting shall pay $4, as dues for the current year. The initiation fee of juniors shall be $10, and their annual dues shall be $5 per year, payable in advance. Any member or associate may become, by the payment of $150 at any one time, a life member or associate, and shall not be liable thereafter to annual dues.

Prof. Robt. H. Thurston was elected President.

IRON AND STEEL NOTES.

THE DEPHOSPHORIZATION OF IRON.—At the Cleveland Institution of Engineers at Middlesborough, Mr. J. E. Stead (Pattinson and Stead), analytical chemist, read a paper on the dephosphorization of iron. He said that he had made several experiments to ascertain the effect of manganese upon phosphate of lime, and also upon phosphate of manganese. Into the bottom of a small basic-lined crucible he placed 1½ grammes of phosphate of manganese, containing 71½ per cent. of manganese. In a second crucible a similar quantity of phosphate of lime was placed, and on the top of it the same quantity of ferro-manganese, which was carefully covered over with more phosphate of lime. Into a third crucible he also placed phosphate of lime, and over it 5 grammes of carburretted iron, containing little or no phosphorus. All these crucibles were placed side by side in a large plumbago crucible, imbedded firmly in powdered basic bricks, and after the covers were securely placed, they were covered with about one inch more of powdered lime. The lid was then placed upon the crucible, which was impounded into a furnace and heated to whiteness for about an hour. It was then removed, and the fused metallic buttons taken out and subjected to analysis. The button from the crucible which held phosphate of manganese contained 67.6 per cent. of manganese, and an increase of 1 per cent. of phosphorus. That from the crucible containing phosphate of lime had increased a little over 1 per cent., the manganese being respectively 67.6 and 68.6 per cent. The phosphorus in the decarbonized iron, which was treated in a similar manner to ferro-manganese for comparison, had not increased above one tenth or 1 per cent. In another experiment, where the crucible was kept in the furnace for a greater length of time, it was shown that nearly 5 per cent. of phosphorus had been gained by the metallic button of ferro-manganese. Judging from these results he thought it was very clear that manganese not only powerfully acted upon the phosphoric acid contained in phosphate of manganese, but it also had a great reducing effect upon the phosphoric acid contained in phosphate of lime. He thought that those results went to prove that it was manganese which reduced phosphoric acid from the cinder in the Bessemer converter. The matter deserved more investigation, and what between the results obtained by Mons. Pourcel and himself (Mr. Stead) he thought that before long he would be able to give a most satisfactory explanation of this phenomenon. The fact that manganese reduced its own phosphate showed them that the metal, subjected to the dephosphorizing process in which it was the object to remove the phosphorus before the elimination of the carbon, told them directly that it must be as free as possible from that element, for as long as mangenese existed in the metal it would have a tendency to reduce any phosphate of manganese or lime produced during the early stages of the blow. Attention had been drawn to the great desirability of supersaturating the scoria with lime, in order that the life of the linings might be prolonged. Great advantage had, it was stated, been obtained on the Continent by the use of iron containing little or no silicon, and an increased proportion of phosphorus. Several methods had been proposed to bring such iron to the converter. The first was that which was being practically carried out at Hörde, where white iron containing about ½ per cent. of silicon was used, together with a sufficient quantity of phosphide of iron, made specially for the purpose of giving the necessary amount of heat in blowing. The second was that which consisted in blowing out the silicon from the metal in a ganister-lined converter, running off the slag and then transferring the desiliconized iron at an increased temperature to the converter lined with basic bricks. This had been carried out at Messrs. Bolckow, Vaughan & Co.'s steel works at Eston. The third method was that described by Mr. Warner, in which he proposed to smelt with the Cleveland iron ore a sufficient quantity of the basic slag or phosphoretic material to give an increased proportion of phosphorus in the iron, and to desiliconize this iron with a mixture of soda ash and limestone, which he (Mr. Stead) confessed was the most rapid and complete process of refining that had ever yet been before the public. The desiliconized iron, after leaving the desiliconized converter, was taken to the Bessemer vessel, and there blown in the usual way. There were other methods of purification, one of which was that of Bacon and Thomas, in which oxide of iron and limestone was charged together with pig iron in a cupola furnace, and the whole were melted down together. This method effected a more or less

complete removal of silicon, which depended altogether upon the quantity of oxide of iron charged. The question as to which of those processes would ultimately be found most practicable and least costly was one which experience only could answer. Messrs. Krupp have patented a slight modification of this process, and, if it was thoroughly successful, the refined iron would be very valuable for puddling processes, but for the Bessemer converter would be almost useless. With reference to an important point—the disposal and utilization of basic slag—Mr. Stead said that although it contained between 20 and 40 per cent. of phosphate of lime, the presence of from 5 to 15 per cent. of combined iron made manure manufacturers think that it would not answer to make superphosphate of lime from it. It seemed to him that as a manure it would be most valuable in a raw state, after grinding to a fine powder. The cinder, especially that which was least silicious, was valunble as a means of increasing the proportion of phosphorus in pig iron, where the amount naturally was not high enough to give the necessary amount of heat in the converter, and also as a flux for blast-furnaces. Excepting the phosphoric acid, slag of such a nature was more valuable than an equal weight of limestone, for the metallic shots of combined iron would be obtained, and the manganese would probably have an influence in removing sulphur from the metal in the blast-furnace, or perhaps, to state the matter more correctly, would prevent it from entering into combination with the iron.

Mr. Thomas, after complimenting Mr. Stead on the ability of his paper, pointed out what had been done on the Continent with reference to the desphosphorization of iron. Perhaps the most important result that had been attained during the past six months was the complete demonstration that had been afforded of the truth of the propositions advanced some eighteen months ago, by which, in the ordinary Bessemer process, white pig could be advantageously substituted for grey Bessemer pig. The advantages of this substitution were over cold As they all knew, a furnace working on white produced far more, and with a smaller expenditure of fuel, than when working on grey iron. There were many furnaces considerably smaller than the larger Cleveland type, which were to-day producing weekly considerably over 700 tons of white pig. Then, the waste in converting the white pig is very much smaller than when working on grey silicious iron. He was glad to say that they had within the past few weeks almost surmounted the gathering at the throat of the converter, which had proved so serious an inconvenience at Eston and elsewhere, by a very simple device. So far they had not succeeded in obtaining rapid working, but they were rapidly pulling up on the Continent. Their production from four five-ton vessels was from thirty to thirty-five thousand tons, which was considered fair enough, and to that rate they had nearly attained. But Mr. Richards and the big mill at Eston were not so easily satisfied. They were all satisfied to emulate American and the best English practice, and to do that modifications of the existing plant were necessary which they had hitherto not thought it expedient to insist on, but which were indispensable for quick working. He might say, however, that they were now spending some money to enable a large output to be produced. Five new Bessemer works were being built expressly for this process at a cost of five or six million francs.

In answer to a question which had been put to him as to when they would see the new steel in the market in large quantities, he said that the five new works he had just referred to would have a capacity of over a quarter of a million tons per year if required, and nine or ten existing Bessemer works had already decided on adopting the process, or were already working it It seemed probable that steel from phosphoric pig-iron would be speedily seen in large quantities. At present the production was small—probably not more than fourteen or fifteen hundred tons per week ; and he had no hesitation in saying that when the alterations now being carried out at the works already in operation were completed, that production would be doubled. As to the prospects of the steel industry in Cleveland, he would venture no opinion, as it was a question they were better qualified to decide for themselves. He might, however, mention the fact that Cleveland pig-iron had been purchased in Middlesborough, taken to the Continent, and there converted into steel, and sold in successful competition with English steel for the American market, at a very satisfactory profit. After a few further remarks, he said he was glad of the opportunity of expressing the obligation Mr. Gilchrist and himself were under to many gentlemen in the Cleveland district who had so materially assisted them in bringing the dephosphorizing question to its present condition, and he wished specially to mention Mr. Winsor Richards, manager of Messrs. Bolckow, Vaughan & Co., and Mr. J. E. Stead, of the firm of Pattinson & Stead, analytical chemists, the latter of whom, he discovered long ago, was always ready to act as an impartial and most accurate critic of the crude hypotheses which constantly occurred to them, as affording possible clues to the solution of practical difficulties, and they had never failed to avail themselves of such suggestions.—*Iron.*

RAILWAY NOTES.

It is proposed to construct a railway from Hambantota to Uva, Ceylon. The present means of transport of the produce of Uva, a large and populous district, is entirely by bullock carts *via* Ratnapura to Colombo; *via* Newera Elliya to Gampola; and a small percentage finds an outlet by the Batticaloa road. The great bulk of the traffic passes over the Ratnapura road to Colombo; which is 112 miles from Haputale, 136 from Badulla, and 170 from Madulsima. The cost of transport is excessively expensive on account of the great distance from the seaboard; from the losses that have to be sustained by planters in having their coffee stolen from the carts on the road to Colombo; from the deterioration of the crop by being so long on the road; from the uncer-

tainty of transport on account of the mortality of bullocks in unhealthy years, and from the stoppage of traffic by the land slips that are constantly occurring at Halpé. The Government of Ceylon have surveyed a line of railway from Navalapitiya—the present terminus of the existing railway—*via* Nanoo Oya and Happutale Pass into Badulla. It is expected that tenders for the construction of the first section will be invited within a month or two; but as the present portion of the line from Nanoo and Badulla will be very heavy, it is, according to a circular by Mr. H. K. Rutherford, not to be proceeded with.

MR. W. T. GUNSON'S improved system of tramways, referred to in a previous number, was again discussed by the members of the Manchester Scientific and Mechanical Society at their meeting on Friday. The president—Mr. J. Bowes—thought that, although the system was a step in the right direction, there were yet some practical defects which would militate against its adoption. One objection would be the amount of skilled labor which would be required in laying, and he thought the smooth surface of the sleepers would be a disadvantage. Mr. A. Jacobs, Borough Engineer, Salford, also thought the sleepers would work smooth, but he chiefly criticised Mr. Gunson's estimates of cost, which, in his opinion, were considerably below the mark. Mr. McLeod thought a difficulty would be found in the expansion and contraction of the rails, whilst Mr. Heys thought this would be counteracted by the other materials, and with regard to the sleepers, added that he did not consider a smooth surface necessarily a slippery one. Mr. Savage, Deputy Superintendent of the Manchester Fire Brigade, thought that the oscillation which he had found, caused to the fire engines in riding through the streets by the present tramway, would be obviated by Mr. Gunson's system. Mr. Gunson having replied upon the discussion, in which he said no serious objections had been raised to his system, and having defended the estimates laid down, the president closed the proceedings by observing that four or five different systems of tramways had already been submitted to the society, but he thought they would agree with him that Mr. Gunson's was the best they had yet the opportunity of discussing.

ENGINEERING STRUCTURES.

THE TAY BRIDGE.—At a meeting of the Institution of Engineers and Ship-Builders in Scotland, Mr. St. John Vincent Day gave a detailed account of observations made by himself and a number of members of the institution of the remains of the Tay Bridge, in which he showed that the bridge was in some instances not only defective in design but inferior in workmanship. He explained that the castings showed in several places that they had been poured too cold, were irregular in thickness and in some cases castings were found with blown holes which had been filled with lead. Evidently, then, he said, some persons engaged in he work must have been cognizant during the whole life of the bridge of at least one vital element of its insecurity, for the lead evidently was designedly put there. He likewise pointed out that the flanges of the piers had not been properly brought together, and in one case the inspecting party had found a space of 14 inches where the concrete had spread out between the flanges. A headless bolt, which had been painted over, was also found. These facts spoke for themselves but too terribly to the members of the Institute of Engineers.

Mr. James G. Fairweather, Edinburgh, said that in common with every engineer in the country, he deeply sympathized with Sir Thomas Bouch in his present position. He was extremely desirous, however, that the true cause of this unparalleled engineering disaster should be as satisfactorily brought to light as the cause of the explosion of the 38-ton gun on board H.M.S. *Thunderer*. One of the principal defects of the bridge, he held, was the want of breadth of base. The piers were almost parallel, and his opinion was that they should have been spread out—even in Sir Thomas Bouch's other design he had them thus placed. His belief was that the bridge had been blown over, just in consequence of the want of breadth of the piers. The bridge would have fallen on the 28th December, even although the train had not crossed it that night; but at the same time he believed that the train assisted considerably the other forces then acting. Then the insufficiency of the length of the holding bolts was but too plainly seen in the case of two or three of the piers, and it certainly would seem absurd, to say the least of it, to have holding down bolts capable of lifting, before breaking, say about 200 tons, and that they were, in some cases at least, only attached to two courses of ashlar 15 inches thick, weighing, say, about six or seven tons. That these columns should have been cast on their side seemed monstrous, and he should say that any engineer who omitted to specify that the columns were to be cast on end would be deserving of censure.

Mr. Page said that Mr. Day's report of what the party of Glasgow engineers who visited the bridge saw was very faithful. He would just add that he never saw such shamefully bad work. The masonry was very bad indeed, and the ironwork was very bad also. Indeed, he never saw such bad in his life.

Mr. John Thomson said along with the others he had visited the bridge on the previous day, and he thought there was much about the structure and the circumstances of its fall which the Institution might well consider. The ties were entirely the weak part of the structure. They were mere ribbons, and it was perfectly clear that the whole bridge had collapsed like a parallel ruler. He thought the bridge had the elements of destruction in itself, and that it was a mere question of time how long it would stand. Many of the bolts they saw had old cracks in them. A great deal had been said about the use of cast iron and the castings, but he did not think the destruction of the bridge rested with the castings. His opinion was, that had the columns—they were too small—been properly stayed with stiffening stays, and not been merely tied with mere ribbons, the ca

tastrophe would not have occurred. It ought to have been so stiff that it should have turned over itself without collapsing. It was evident that the snugs broke off, and the columns just collapsed. It was a serious question whether or not it was possible to do anything with the rest of the bridge—whether it would have to be taken down, or the portions at present standing made use of in the reconstruction. His opinion was that the remaining parts could be so strained up by diagonal struts as would make it of sufficient rigidity to sustain the work it had to do without taking it down. The curve that was made at the north end of the bridge was, he considered, a fatal defect in itself, and he thought that it was unfortunate that there should have been such a gradient at this particular portion. The trains ran over that part at a very high rate of speed, and an engineer friend in Dundee, who had often timed the trains, told him that at the high girders the trains ran at the rate of from 40 to 43 miles per hour. That, they knew, was very much more than the authorized rate. In any future reconstruction of the bridge it would be necessary that there should be some very strong stiffening studs in a direct line with the force on the south side.

Mr. Gale said he was one of those who thought that, however strongly the piers had been braced together, the bridge would have been blown over on the occasion that it was. It could very easily be shown that a wind pressure of 35 lbs. on the square foot would have been sufficient to have thrown one of the long girders into the sea, quite irrespective of the manner in which the pier was braced. If the pier had been stronger in the bracing the result would simply have been that the girder would have been thrown a little further from the piers, but here the bridge dropped right down at the root of the piers, just as a chimney stalk fell when blown over by the wind. There was, however, no bracing that would have preserved the bridge from ultimate destruction.

ORDNANCE AND NAVAL.

CLYDE SHIPBUILDING IN 1879.—The returns of the tonnage of vessels launched on the Clyde during the year drawing to a close show a falling off compared with 1878, of 49,150 tons, but compared with 1877 an increase of 3,493 tons. This state of matters is sufficiently accounted for by the great depression which prevailed during the first ten months of the year. During the last two months the prospects have greatly brightened, and at the present time there is a large amount of work on hand which will materially affect next year's figures. The total number of vessels launched on the river during the year was 170 of an aggregate tonnage of 173,438 tons, as compared with 236 vessels and 222,353 tons in 1878. One feature of the work of the year has been the number of steel-built vessels launched, which have reached an aggregate of 18,808 tons. Messrs. Denney and Brothers, of Dumbarton, have built no fewer than ten of these ships. These included a steamer of 4000 tons for Messrs. J. and A. Allan's Transatlantic service, and two steamers for the Union Steamship Company of Australia of 1728 and 1653 respectively. Messrs. John Elder & Co. built for Messrs. Donald Currie and Co.'s Cape Mail service a steel vessel of 3000 tons; and Messrs. R. Napier and Sons, Govan, two steel steamers of 2520 tons each for the Pacific Steam Navigation Company. Several important additions were made during the year to the great ocean-carrying companies. The chief of these were the *Orient*, 5386 tons, for the Orient Steam Navigation Company, and the *Arizona*, 5,147 tons, Guion Line. Both these vessels were built by Messrs John Elder & Co., Govan. During the last two years several vessels of large dimensions have been constructed on the Clyde, while other monster ships are either in the hands of builders or are being planned by naval architects. Competition amongst the great line of ocean steamers has of late become extensively keen, and there is an evident desire on the part of the ship owners to outstrip each other in the dimensions of their vessels. Whatever qualifications must be possessed by the ocean steamships of the immediate future, it is interesting to note that great size is likely to be one of their characteristics. A few details regarding the large vessels recently built, and for the sake of comparison, the largest ship afloat (the *Great Eastern*), will be of interest at the present time. Last year Messrs. J. and G. Thomson, Clyde Bank, built the *Gallia*, a Cunard Liner, of the following dimensions:—Length over all, 450 feet; breadth, 44 feet; depth, 36 feet. The tonnage of the *Gallia* is 5200 tons. During the present year Messrs. John Elder & Co., Govan, completed two large, powerful steamers, each over 5000 tons. The *Arizona*, built by Messrs. Elder & Co., for the Guion line, is 465 feet long, 46 feet broad, and 37 feet in depth, her tonnage being 5300 tons. She is capable of carrying a dead weight of cargo, exclusive of 1200 tons of coal in the bunkers, of 2600 tons. The second large vessel built this year by Messrs. Elder & Co. was the *Orient*, a steamer of the following dimensions:—Length, 460 feet; breadth, 46 feet 6 inches; depth, 37 feet 8 inches; tonnage, 5386 tons. The *Orient*, which was the largest vessel ever lanched on the Clyde, has a displacement at load draught of over 9500 tons. But the Cunard Company are having built for them by Messrs. J. and G. Thomson, Clyde Bank, a steamer larger than either the *Arizona* or the *Orient*, and exceeded in size by the *Great Eastern* only. The new vessel will be 7500 tons and 10,000 horse-power, her dimensions being 500 feet in length, 50 feet in breadth, and 41 in depth. No sooner had the Cunard Company announced their intention to build a vessel second in point of size to the *Great Eastern* only than the Inman Company determined to add to their Transatlantic service a steamship of even still larger dimensions. The contract for the new Inman Liner has not yet been closed, but we understand that it has been resolved to have it built at Barrow, and that it is to be an 8000-tonner. The length of the *Great Eastern* on load waterline is 680 feet, breadth extreme 82 feet 6 inches, and her depth at the side is 58 feet. Her tonnage, according to builder's measurement, is

22,627 tons; her register tonnage, including engine space, is 18,914 tons; and her register tonnage excluding engine space is 13,343 tons. She has stowage for cargo to the extent of 6000 tons, and the capacity in her coal bunkers 10,000 tons Her draught of water light is 15 feet, and her water draught loaded is 30 feet. The displacement of the vessel when light is 11,844 tons, and her displacement loaded is 27,384 tons. She has accommodation for 800 first-class, 2000 second-class and 1200 third-class passengers, but if required for troops alone she could carry 10,000 men. It will thus be seen that the *Great Eastern* is in point of size considerably ahead of anything yet ventured by ship owners, and though there is an evident desire to increase the size of the great ocean steamers, the position of Mr Scott Russell's ship as the largest afloat is not likely to be disputed.

CONVERSION OF A WOOLWICH PATTERN-GUN. One of the Woolwich pattern guns converted into a breech-loader for experiment has been conveyed to Shoeburyness for long-range practice. The breech apparatus is on the screw principle, adopted for the breech-loaders now in course of manufacture. It is also proposed to send to Shoeburyness two other converted breech loaders—one a 40-pounder Armstrong with the trunnions turned so as to place the wedge at the side instead of the top of the piece to allow of its being easily drawn out, and the other a 31-pounder cast iron gun altered in imitation of the Krupp system. These guns have all been tried at Woolwich, and the superiority displayed by the first-named has induced the Ordnance Select Committee to recommend its adoption as the pattern of the new service weapons.

THE "DUILIO"—The Italian monster iron-clad, *Duilio*, has just been put in commission. She represents 22,000,000 francs, and the Italian navy waits the experiment of her performances for its definite systematization. She is now at Spezia. Her displacement is 11,500 tons; nominal horsepower, 7,500. All heavy work aboard, as steering, regulating ventilators, removal of cinders, weighing anchor, is done by steam. There are thirty-three special engines. She carries four 100-ton guns, worked by special and, in part, newly-invented machinery; also twelve smaller guns and four mitrailleuses. A broadside of her four great guns throws 8,000 lb. weight of metal, consumes 2,000 lbs. of powder, and, comprising projectiles, costs 4,000 fr. At each broadside a force is developed sufficient to raise 48,000 tons to the height of 1 meter. She is expected to attain a speed of 12½ knots, and doing so will consume 15,000 lbs. of coal an hour. She carries a Thorneycroft torpedo boat, 22 meters long, which has attained a speed of 21 knots. She starts on her trial trips immediately.

BOOK NOTICES.

SEWERS AND DRAINS FOR POPULOUS DISTRICTS. By JULIUS W. ADAMS, C E., New York: D. Van Nostrand. Price $2 50.

The name of the author of the above work is a sufficient guarantee for its value. Mr. Adams holds so high a place among American engineers, and has for so many years been an acknowledged leader in the profession, that the importance of anything from his pen is sure to be recognized. It is not often that our best engineers can be induced to record the results of their practice. This is much to be regretted, as the life-long experience of these men would be a precious heirloom to the rising race of engineers. The market is flooded with volumes written by men of no experience except in making books, many of them couched in language utterly unintelligible to any except professional mathematicians, to read which is like threshing a bushel of chaff to find a single grain of wheat; while the works of real practical value, which are found thumbed and worn by use in engineers' offices, are so few that they may be counted on the fingers. Yet in their works our engineers have stored up an immense amount of the most valuable instruction, exactly adapted to the use of the younger members of the profession.

The work above referred to adds a volume to the list of books which working engineers will be sure to appreciate. Mr. Adams having designed, with great care, the sewerage system for the city of Brooklyn, embracing an area of some twenty square miles, which, after twenty years of service, has shown no defect in the principle adopted, can hardly fail to give us valuable information. Indeed, he would have done a great service if he had simply described the sewerage works of Brooklyn. But he has done more. He has put the whole subject in a systematic and practical form, under the several heads—Physical Outline of the District, Rainfall, Water Supply, Disposal of Sewage, Preparation of Plans Materials Used in Construction of Sewers, Foundations, Appendages to Sewers, Street Basins, Tide Valves, Storm Sewers, Intercepting Sewers, Ventilation of Sewers and House Drainage.

The work is full of good sound practical information, and is sure to be of great service to the profession. GEORGE L. VOSE.

SANITARY ENGINEERING. Second Edition. By WILLIAM CAIN, C. E., Member of the North Carolina Board of Health, Raleigh, N. C., 1880.

This very interesting work is issued by the North Carolina Board of Health, and commences with general remarks upon "Death Rates lowered by Sanitary Works," and references are made to Latham's "Sanitary Engineering," and tables given, showing a decrease of death rates owing to proper sewerage. The rate of St. Louis, Mo., from 1867 (when the Board of Health was established) to 1877, was actually decreased, although the population had doubled in that decade. Prof. Cain claims that cleanliness of cities is the principal cause of lessened rates, and treats of the necessity of proper sewerage systems, of the free use of water, of methods for ventilating residences, of the drainage of soils, and of the pernicious influence proceeding from absence of sub-soil drainage. In rural residences he illustrates the

disastrous effects of arranging sink spouts and noxious collections so that wells will become contaminated by the poisonous filterings. The work gives full and clear directions for remedying the evils spoken of.

The book is in pamphlet form and contains nearly one hundred pages.—*Eng. News.*

ANALYTICAL CHEMISTRY. By W. DITTMAR. London and Edinburgh: W. & R. Chambers. For sale by D. Van Nostrand. Price, 60 cts.

This petite volume is a neat compendium of laboratory analysis adapted to the needs, more particularly of, medical students. The determination of sugar and urea being dwelt upon at considerable length and with satisfactory clearness.

THE PRINCIPLES OF GRAPHIC STATICS. By GEO. SYDENHAM CLARKE. London: E. & F. N. Spon. For sale by D. Van Nostrand. Price, $5.50

The special feature of this work, which serves to distinguish it from other English treatises on this subject, lies in the treatment of the problems relating to the moment of inertia and moment of resistance.

The book is a well printed quarto, with excellent diagrams.

CALCULATOR OF MEASUREMENT OF PACKAGES BY FRACTIONS OF AN INCH. In two volumes. By MANEKJI KAVASJI TADIVALA, Shroff. Bombay: Printed at the Caxton Steam Printing Press. London: Simpkin, Marshall & Co. For sale by D. Van Nostrand.

Here we have before us a work by a native of India, which bears on the face of it evidence of its being the result of great mental labor and application for a very considerable length of time. Nothing could be more laudable and worthy of encouragement than the compiler's object, which was to produce a book that should be worthy of being adopted as a standard of metage between shipowners and consignees in estimating the amount of freight on measurement goods, in order to prevent disputes.

Hitherto it appears to have been the custom in calculating the measurement of bales, boxes, hogsheads, and other packages of what is termed light goods for freight, to offset the fractions of inches in dimensions by balancing them one against the other, as nearly as might be, for the facility and dispatch of working by whole numbers. And that system was, of course, liable to doubt and question, because it was only an approximation towards accuracy; and this laborious and carefully prepared work was undertaken, it seems, in the just expectation that it would be appreciated and adopted by the mercantile world, and in all parts of the globe, as a ready-reckoner of exact dimensions for every description of package or production which modern trade is accustomed to class as light goods in the stowage of ships.

The method of the compiler, though at first it looks a little perplexing, becomes simple, intelligible, and easy of application as soon as his explanation is perused. Every bale or package is assumed to be evensided, and practically reducible to three principal measurements, like an ordinary piece of squared timber—length, breadth and thickness—and the contents are found to the hundredth part of an inch, by using in every case two places of decimals. The starting point is at 6 inches long, 6 inches wide and 6 inches deep, and advancing gradually by quarter inches to the largest sized packages. Some idea may be formed of the immense number of separate sums which had to be performed and repeated before such a work could be presented to the public complete and accurate in all its parts, when we mention that about 450,000 such calculations are comprised in each volume, in verification of which certificates of accuracy from eminent and well-known authorities are quoted by the author in his preface.

Every quarter of an inch increase in the smallest of the three dimensions has sixteen pages of contents assigned to it at the various breadths of the other side, and the variations of length are also calculated to quarter inches, so that every case that can occur is provided for, and if a package or piece of merchandise-timber, for instance, exceed the length of the longest measurement set down, it is but necessary to take a section of it, say the half, quarter, or even one-eighth, and having found the contents of that, multiply it by the denominator of the fraction, and you have the true contents of the whole piece to the hundredth part of an inch, as if it had been so stated in the book. Such a work, of course, appeals strongly to the general body of the mercantile community in every nation and language, for scarcely more than three or four words of English, apart from the brief introductory explanation, require to be known to render it intelligible to all civilized peoples; *length, breadth*, and *depth* or *thickness* comprise its chief vocabulary, the rest consists of figures, which are universally understood. There is little to be read, but an immense deal to refer to, and the foreign trade of the world would be greatly facilitated by having such a standard of measurement to go by. That this work is not unworthy of such a high and authoritative position may be presumed from the circumstance that most of the eminent houses and great trading bodies of Bombay, Madras and Calcutta, as well as those of many other ports in the Indian seas and elsewhere, have given their names as subscribers to it and adherents to the author's system. This is of itself an immense testimony and recommendation, and there seems every probability that the time, money and intelligence which must have been so largely employed in getting up and producing to the world this really valuable work will, in the end, be amply rewarded. The two volumes are in large octovo, neatly bound in cloth, containing between seven and eight hundred pages each, and no shipper or shipowner's office should be without them.

We need only add that the way these volumes are turned out of hand is, we consider, highly creditable to the Caxton Press of Bombay.

AID TO SURVEY PRACTICE. By LOWIS D. A. JACKSON, A.-M.I.C.E. London: Crosby Lockwood & Co. For sale by D. Van Nostrand. Price $5.00.

This book, which the author modestly calls a "small work on survey practice," will, we think, be found of considerable value to young surveyors and to articled pupils, for it had its origin in this way: Mr. Jackson, in his search for a work on Surveying, to put into the hands of his pupils, found many books excellent in their way, but none which would serve the purposes of the student and form a general book of reference for methods, formulæ, and forms of record. There was, in fact, no book that could be regarded as a general guide in survey practice, but the student anxious to acquire a tolerably wide knowledge of his profession would have needed a small library of books on different branches of the subject. Under these circumstances, Mr. Jackson was, perforce, compelled to give written instructions to his pupils, and these notes, condensed and revised, now appear in a moderate-sized volume for reference in surveying, leveling and setting out, and in route-surveys of travelers by land and sea. A considerable portion of the book is reprinted from the author's "Curve-book," and though some of the methods described are strictly original, in every case the systems are those which have been tested in practice. In many respects it will be useful to the trained surveyor, for it will enable him to refresh his memory and to shorten his labor by the use of tables and formulæ; while to those whose survey practice has been limited it will be a vade-mecum. The author says, however, that he did not write the book with the idea of making an utterly inexperienced person a surveyor, for that is a hopeless task, the art of surveying requiring a thoroughly practical, as well as theoretical knowledge of method. His purpose was to supply a guide, and he has certainly accomplished it. The work is divided into four parts, viz., general surveys, leveling, setting-out and route surveys, with a selection of field records to illustrate the text. There are also some page plates of different surveys to match the field records, and a number of diagrams to elucidate the text. The book is, in fact, almost indispensable to the student, while the traveler will find just the information he wants to enable him to take an ordinary route-survey, and to indicate with accuracy the general features of a district.—*English Mechanic.*

A TREATISE ON STATICS.—By GEO. M. MINCHIN, M.A. Oxford and London: McMillan & Co. For sale by D. Van Nostrand. Price $4.00.

This is the second edition, corrected and enlarged, of a treatise on the fundamental principles of electrostatics and elasticity, which has found a place in the Clarendon Press series. The author, who is Professor of Applied Mathematics at Cooper's Hill, acknowledges the labors of correspondents who have supplied him with corrections of errors and lists of misprints, and in the present edition he believes that few can remain. The examples have been rearranged with reference to their relative difficulty, and some have been omitted, as being purely mathematical and fantastic. Some more important alterations or additions have been made, notably the introduction of a chapter on "Strains and Stresses," the author thinking that, in view of the enormous development of mathematical physics and the wonderful modern inventions depending on small strains and vibrations of natural solids, the study of the equilibrium and motion of bodies as they are, and not as they exist in abstraction, is a subject of which it is impossible to exaggerate the importance. He is clearly of opinion that too much valuable time is spent in the discussion of neat mathematical realities, though he is fully alive to the necessity for spending some time in such work. The chapter on strains and stresses refers mainly to the theories of light, magnetism and electricity, and are written for students who have attained proficiency in pure mathematics. For the view of the theory of friction presented in these pages the author is indebted almost entirely to Mr. Jellett, who has in his lectures and his treatise on the subject completely elaborated it. This volume will, we think, be the recognized text-book on statics in many of the higher schools and colleges, but it is rather too far advanced for those who are endeavoring by themselves to acquire the knowledge necessary to solve the problems which are daily cropping up in connection with mathematical physics. Those who are well grounded in the ordinary mathematics of the schools will be able to read it with advantage, and progress steadily to the higher branches; but the student who thoroughly comprehends all that is contained between the two covers of Prof. Minchin's "Statics" is very fairly equipped to battle with modern questions in electrostatics.—*Eng. Mechanic.*

MISCELLANEOUS.

A NEW METALLIC COMPOUND.—On Wednesday evening last Dr. Granville Cole read a paper before the Society of Arts on a new metallic compound discovered by Mr. J. Berger Spence, and its application to industrial and artistic purposes. The substance in question belongs to the class known as thiates or sulphur sulphides. Nearly a year ago Mr. J. Berger Spence discovered that the sulphides of metals, combined with molten sulphur, formed a liquid. This liquid, on cooling, became a solid, homogeneous mass, possessing great tenacity, and having a peculiar dark grey, almost black color. It has a comparatively low melting point, viz., 320° Fah., or rather more than 100° above the temperature of boiling water. There is thus in its favor the small amount of fuel needful to supply the necessary heat for reducing the metal to a condition for use. It expands on cooling, a property not shared by the majority of other metals or metallic compounds, and for an operation like the joining of gas and water pipes this expanding property is one of great importance. It claims to resist atmospheric or climatic influences, as compared with bronze and marble. As compared with other metals or metallic compounds, its resist-

ance of acids, is certainly superior. A smooth surface of this metal or metallic compound, now known commercially as Spence's metal, takes a very high polish.

These qualities tend to render the new compound very useful in many ways. The advantages which Spence's metal possesses over other materials used for artistic productions, may be summarized under three heads, viz., cheapness, facility of working, and resistance to climatic influences. As compared with lead, which is one of the cheapest of metals, it is one-third the weight; and whereas the average cost of lead for the last ten yeas has been nearly £18 a ton, Spence's metal only costs £15. A ton of Spence's metal being three times the amount in bulk of that of a ton of lead, it is available for three times the amount of work. It may, therefore, be considered to be nearly a quarter of the price of lead, and, consequently, very considerably less than that of bronze. Its melting point being very low, allows it to be very easily prepared for pouring into a mould, and its property of expansion, when cooling, causes it to take such a perfect impression, that the cast requires very little chasing after. In respect of a gelatine mould, which can cover a considerable surface of work without joints such as one has to make in plaster piece moulding, the metal cast obtained from such a mould would require no chasing. With regard to its resistance to climatic influences, experiments have been conducted in this direction with complete success. A polished surface of the metal has been exposed for six months in all weathers, without showing the least change.

Experiments have been made which show its great suitability for joining gas and water pipes, and from a sanitary point of view, as water has no action upon it, it would be extremely valuable for cisterns, and being almost a non-conductor of cold, pipes might be lined with it to prevent the water from freezing. To chemical manufacturers, the metal being less acted upon by acids than other metals, it may also be of service, especially as regards sulphuric acid, which is the most extensively used of all acids in commerce. The new metal has been tested with sulphuric acid, and its action is almost imperceptible. The one objection to the use of this metal in this case is its low fusing point, but when acids have only to be used up to a certain temperature, say 200° Fah., a large field may be predicted for its use. Besides the uses thus enumerated, Dr. Cole indicated many others to which the metal may be applied; for instance, joining iron to stone or wood, the tensile strain of the metal being from 650 lbs. to the square inch five minutes after setting. For joining railings to stone it would, he said, answer equally as well as lead, and be very much less in cost; also for coating the holds of ships. It might also be used for hermetically sealing bottles; for covering cloth; for covering parcels that are being sent out to hot climates, thus obviating the use of the lined boxes; for preserving fruit, or other articles of consumption.

ANCIENT PETROLEUM.—Professor Skeat has printed in the *Athenæum* a passage from North's translation of "Plutarch's Lives" (1631, p. 702), from which it appears that Petroleum was known in the time of Alexander the Great. The passage runs as follows:—"For a Macedonian called Proxenus, that had charge of the kings carriage [baggage], as he digged in a certaine place by the riuer of Oxus, to set vp the kings tent and his lodging, he found a certaine fat and oily veine, which after they had drawn out the first, there came out also another clearer, which differed nothing, neither in smell, taste, or savour from natural oile, having the glosse and fatness so like, as there could be discerned no difference between them: the which was so much the more to be wondered at, because in all that country there were no oliues.

THE rival merits of the Mont Blanc and Simplon routes for the new railway tunnel through the Alps have recently been attracting a good deal of attention in Switzerland and Savoy. The Swiss at first considered the proposal to drive a tunnel through Mont Blanc instead of the Simplon hardly worth notice; but since it has been taken up with such spirit by M. Chardon, a member of the French Senate, the project has assumed practical importance, and has received serious attention. In Switzerland, the Mont Blanc route is not, says the *Times*, regarded with favor, partly because it would not touch Swiss territory. The supporters of the Simplon route, moreover, urge that the line from Calais to Plaisance through the Simplon is 136 kilometers shorter than that through Mont Blanc, and that the Simplon tunnel would be at a level 500 meters lower than that through Mont Blanc. Further, it is pointed out that the lines of approach to the Simplon have already been constructed, while Mont Blanc is far less favorably situate in this respect. In Savoy, on the other hand, the general feeling is strongly in favor of the Mont Blanc route—first, because it would be on French territory; and, secondly, because it would greatly benefit the Savoyards.

THE SUEZ CANAL.—The total receipts of the Suez Canal for the year 1879, were £1,185,200. This showed a decrease of £58,700 on 1878, which year itself was £67,100 worse than its predecessors. As might be expected, however, the later months of 1879 were much more satisfactory than the previous period of the same year. The receipts for December were £107,600, an increase of £9,200 on the same month of 1878. The return for the first half of January shows an increase on that of the same period last year of £20,800. Should the favorable tendency here indicated continue, they will be another proof of the reality of the improvement that has taken place in the trade of the world at large.